

PRIVATE
DEPOSITORY

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

ANNUAL REPORT OF THE COUNCIL.

VOL. LX. No. 5. FEBRUARY 1900.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LX.

FEBRUARY 9, 1900.

No. 5

Professor G. H. DARWIN, M.A., LL.D., F.R.S., PRESIDENT,
in the Chair;

William Henry Robinson, Offendene, Walsall, Staffordshire,
was balloted for and duly elected a Fellow of the Society.

The following Candidate was proposed for election as a
Fellow of the Society :—

Thomas C. Bush, Somerville, Wells Road, Bath (proposed
from personal knowledge by the Rev. D. Higham Sparling).

REPORT OF THE COUNCIL TO THE EIGHTIETH ANNUAL GENERAL MEETING OF THE SOCIETY.

The following table shows the progress and present state of
the Society :—

	Compounders	Annual Subscribers	Total Fellows	Associates	Patron	Grand Total
1898 December 31	247	388	635	44	1	680
Since elected	+ 6	+ 21	...	+ 4	...	...
Deceased	- 3	- 11	...	...	...	...
Resigned	...	- 7	...	...	...	...
Removals	+ 3	- 3	...	...	...	...
Expelled	...	- 6	...	...	...	...
1899 December 31	253	382	635	48	1	684

Mr. Knobel's Account as Treasurer of the Royal

RECEIPTS.

Balances, 1899 January 1:—	£	s.	d.	£	s.	d.
At Bankers', as per Pass-book	542	16	3			
Cheques not credited till 1899	6	6	0			
In hand of Assistant Secretary on account of Turnor and Horrox Fund	2	18	2			
In hand of Assistant Secretary on Petty Cash Account	13	6	1			
				565	6	6
Three quarters' Dividends on £13,200 Consols, 2½ per cent.	263	3	9			
Dividends on £1,250 Metropolitan 3-per-cent. Stock	36	5	0			
„ £932 19 0 Metropolitan 2½-per-cent. Stock	22	11	0			
One quarter Dividend on £3,400 East Indian Rail- way 3-per-cent. Debenture Stock	24	13	0			
Half-year Dividend on £1,100 Commercial Gas Company 4½-per-cent. Debenture Stock ...	23	18	6			
Interest received from Brokers for Stock not delivered	18	11	7			
				389	2	10
Received on account of Subscriptions:—						
Arrears	155	8	0			
Annual Contributions for 1899	594	6	0			
„ „ 1900	6	6	0			
Admission Fees	56	14	0			
First Contributions	38	17	0			
				851	11	0
Composition Fees				168	0	0
Sales of Publications:—						
At Williams and Norgate's, 1898	16	3	6			
At Society's Rooms, 1899	61	13	0			
Sales of Photographs, 1899	23	9	6			
				101	6	0
Received from Mrs. Knott in aid of Expenses of Printing <i>Memoirs</i> , vol. lii.				250	0	0
Income Tax refunded by Commissioners of Inland Revenue				14	2	0

Audited and found correct, January 19, 1900,

RICHARD INWARDS,
W. B. GIBBS.£2,339 8 4

Astronomical Society, from 1899 January 1 to December 31.

EXPENDITURE.

	£	s.	d.	£	s.	d.
Assistant Secretary: Salary	250	0	0			
" " for assistance in editing Society's Publications	50	0	0			
				300	0	0
House Duty	2	12	6			
Fire Insurance	9	9	6			
				12	2	0
Printing, &c., <i>Monthly Notices</i>	353	17	3			
" <i>Memoirs</i> , vol. lii.	366	15	6			
" " vol. liii.	338	5	0			
" List of Fellows and Miscellaneous	24	5	0			
Engraving Blocks for <i>Monthly Notices</i>	4	17	6			
				1,088	0	3
Computation of Ephemerides				15	0	0
Reproduction of Photographs				15	8	4
Turnor and Horrox Fund: Purchases for Library	7	18	2			
Council Grant: ditto	16	1	3			
				23	19	5
Clerk's Wages	40	4	0			
Postage and Telegrams	80	18	7			
Carriage of Parcels	2	12	9			
Stationery (Spottiswoode & Co.)	3	11	4			
Stationery and Office Expenses	5	11	4			
Envelopes for storing Photographs	3	13	0			
Address to Sir G. Stokes	3	18	6			
				140	9	6
Expenses of Meetings	20	0	0			
Lantern Expenses	6	6	8			
Time Signal: Rental of Wire (1898 and 1899)	10	0	0			
				36	6	8
House Expenses	68	8	10			
Coals and Gas	44	3	10			
Electric Lighting	5	19	10			
Furniture, &c.	17	8	0			
Sundry Fittings and Repairs	7	12	8			
Sundries	4	8	8			
				148	1	10
Dallmeyer & Co., for two Abney Lenses				22	13	9
Lee and Janson Fund Grant				5	0	0
Invested (see separate Account)	64	9	3			
Interest from Brokers invested (see separate Account)	18	11	7			
				83	0	10
Cheque-book and Deductions on Cheques				0	10	1
Balances, 1899 December 31:—						
At Bankers', as per Pass-book	400	10	2			
Cheques not credited till 1900	6	6	0			
In hand of Assistant Secretary on account of Council Grant for Purchase of Books	8	18	9			
In hand of Assistant Secretary on Petty Cash Account	18	11	3			
				434	6	2
Cheques outstanding 1898 December 31				14	9	6
				£2,339	8	4
				Y 2		

*Treasurer's Account of the Sale
ordered by the Council*

		£	s.	d.	£	s.	d.
Aug. 10.	To Sale of £13,200 Consolidated 2 $\frac{3}{4}$ - per-cent. Annuities @ 105 $\frac{3}{8}$	...	13,909	10	0		
	Power of Attorney and Stamp	...		0	15	0	
							13,908 15 0
Aug. 15.	To Cash	...	59	16	0		
Oct. 13.	To Interest, 3 per cent. on £1,730 4 6 (Gas Light and Coke Company Stock deferred), Aug. 16 to Oct. 13			8	4	10	
Oct. 27.	To Interest, 3 per cent. on £1,747 5 3 (Stock purchased but not de- livered), Aug. 16 to Oct. 27	...		10	6	9	
Oct. 31.	To Cash	...	4	13	3		
							83 0 10

£13,991 15 10

of Consols and Reinvestment,
1899 June 9.

1899. By purchase of—	£	s.	d.	£	s.	d.
£3,200 London and North-Western Rail- way 3-per-cent. Debenture Stock @ 111 $\frac{1}{4}$	3,560	0	0			
Stamp, Brokerage, &c.	27	1	6			
				3,587	1	6
£3,600 Midland Railway 2 $\frac{1}{2}$ -per-cent. Debenture Stock @ 94	3,384	0	0			
Stamp, Brokerage, &c.	25	12	9			
				3,409	12	9
£3,400 East Indian Railway 3-per-cent. Debenture Stock @ 102	3,468	0	0			
Stamp, Brokerage, &c.	26	7	0			
				3,494	7	0
£1,700 Gas Light and Coke Company 3-per-cent. Debenture Stock @ 101... ..	1,717	0	0			
Stamp, Brokerage, &c.	13	4	6			
				1,730	4	6
£160 Gas Light and Coke Company 3-per-cent. Debenture Stock @ 101... ..	161	12	0			
Stamp, Brokerage, &c.	1	14	10			
				163	6	10
£1,100 Commercial Gas Company 4 $\frac{1}{2}$ - per-cent. Debenture Stock @ 145	1,595	0	0			
Stamp, Brokerage, &c.	12	3	3			
				1,607	3	3
				£13,991	15	10

Report of the Auditors.

We have examined the Treasurer's accounts for the year 1899, and have found and certified the same to be correct. The cash in hand on December 31, 1899, including the balance at the bankers', &c., amounted to £434 6s. 2d.

During the past year considerable changes have been made in the investments of the Society, particulars of which are set forth in the account accompanying this report.

The books, instruments, and other effects in the possession of the Society have been examined, and they appear to be in a satisfactory condition.

We have laid on the table a list of the names of those Fellows who are in arrear for sums due at the last Annual General Meeting of the Society, with the amount due against each Fellow's name.

(Signed) RICHARD INWARDS,
W. B. GIBBS.

Trust Funds.

The Turnor Fund: A sum of £464 18s. East Indian Railway 3-per-cent. Debenture Stock; the interest to be used in the purchase of books for the Library.

The Horrox Memorial Fund: A sum of £103 6s. East Indian Railway 3-per-cent. Debenture Stock; the interest to be used in the purchase of books for the Library.

The Lee and Janson Fund: A sum of £334 10s. 9d. East Indian Railway 3-per-cent. Debenture Stock; the interest to be given by the Council to the widow or orphan of any deceased Fellow of the Society who may stand in need of it.

The Hannah Jackson (née Gwilt) Fund: A sum of £309 18s. 6d. East Indian Railway 3-per-cent. Debenture Stock; the interest to be given in Medals or other awards, in accordance with the terms of the Trust.

Assets and Present Property of the Society, 1900 January 1.

	£	s.	d.	£	s.	d.
Balances, 1899 December 31:—						
At Bankers', as per Pass-book	400	10	2			
Cheques not credited till 1900	6	6	0			
In hand of Assistant Secretary on account of Council Grant for purchase of books ...	8	18	9			
In hand of Assistant Secretary on Petty Cash Account	18	11	3			
				434	6	2
Due on account of Subscriptions:—						
3 Contributions of 5 years' standing	31	10	0			
6 " 4 " 	50	8	0			
7 " 3 " 	44	2	0			
31 " 2 " 	130	4	0			
60 " 1 " 	126	0	0			
2 Admission Fees and First Contributions ...	6	6	0			
	388	10	0			
Less 3 Contributions paid in advance	6	6	0			
				382	4	0
Due from Messrs. Williams and Norgate for sales of Publications during 1899				32	19	10
£3,400 East Indian Railway 3-per-cent. Debenture Stock, including the Turnor Fund, the Horrox Memorial Fund, the Lee and Janson Fund, and the Hannah Jackson (née Gwilt) Fund.						
£3,200 London and North Western Railway 3-per-cent. Debenture Stock.						
£3,600 Midland Railway 2½-per-cent. Debenture Stock.						
£1,860 Gas Light and Coke Co. 3-per-cent. Debenture Stock.						
£1,100 Commercial Gas Company 4½-per-cent. Debenture Stock.						
£1,250 Metropolitan 3-per-cent. Stock.						
£932 19 0 Metropolitan 2½-per-cent. Stock.						
Astronomical and other Manuscripts, Books, Prints, and Instruments.						
Furniture, &c.						
Stock of Publications of the Society.						
Two Gold Medals.						

Stock in hand of volumes of the *Memoirs* :—

Vol.	At Society's Rooms	At Williams & Norgate's	Vol.	At Society's Rooms	At Williams & Norgate's
I. Part 1	7	...	XXXI.	134	...
I. Part 2	41	...	XXXII.	145	...
II. Part 1	50	3	XXXIII.	154	...
II. Part 2	16	3	XXXIV.	157	...
III. Part 1	65	1	XXXV.	104	2
III. Part 2	82	1	XXXVI.	187	8
IV. Part 1	78	3	XXXVII.	330	7
IV. Part 2	89	3	Part 1 XXXVII.	278	8
V.	100	3	Part 2 XXXVIII.	263	1
VI.	117	6	XXXIX.	228	3
VII.	140	3	Part 1 XXXIX.	233	3
VIII.	124	3	Part 2 XL.	248	...
IX.	130	3	XLI.	395	1
X.	142	...	XLII.	224	3
XI.	148	...	XLIII.	223	...
XII.	153	...	XLIV.	206	1
XIII.	153	...	XLV.	238	...
XIV.	360	...	XLVI.	214	2
XV.	134	...	XLVII. Part 1	3	...
XVI.	157	1	XLVII. Part 2	18	...
XVII.	140	1	XLVII. Part 3	2	...
XVIII.	133	1	XLVII. Part 4	10	...
XIX.	143	...	XLVII. Part 5	8	...
XX.	133	1	XLVII. Part 6	9	...
XXI. Part 1	244	...	XLVII.	197	1
XXI. Part 2	98	...	XLVIII. Pt. 1	227	2
XXI. 1 & 2 (together)	54	...	XLVIII. Pt. 2	231	1
XXII.	157	...	XLIX. Part 1	363	...
XXIII.	142	...	XLIX. Part 2	241	...
XXIV.	147	1	L.	235	1
XXV.	153	...	LI.	271	1
XXVI.	163	1	LII.	365	1
XXVII.	417	1	LIII.	394	4
XXVIII.	372	...	Index to <i>Memoirs</i> }	619	1
XXIX.	395	1			
XXX.	147	1			

Stock in hand of volumes of the *Monthly Notices*:—

Vol.	At Society's Rooms	At Williams & Norgate's	Vol.	At Society's Rooms	At Williams & Norgate's
I.	54	...	XXXII.	106	5
II.	58	...	XXXIII.	90	...
III.	...	...	XXXIV.	65	1
IV.	...	...	XXXV.	51	...
V.	...	...	XXXVI.	26	1
VI.	42	...	XXXVII.	31	3
VII.	2	...	XXXVIII.	95	2
VIII.	152	2	XXXIX.	95	...
IX.	24	3	XL.	104	3
X.	171	1	XLI.	103	5
XI.	183	...	XLII.	112	1
XII.	105	2	XLIII.	108	2
XIII.	176	2	XLIV.	111	2
XIV.	175	3	XLV.	115	1
XV.	167	2	XLVI.	108	...
XVI.	154	1	XLVII.	124	2
XVII.	165	1	XLVIII.	118	...
XVIII.	242	...	XLIX.	109	7
XIX.	51	...	L.	109	10
XX.	31	...	LI.	110	8
XXI.	16	...	LII.	108	11
XXII.	30	...	LIII.	112	14
XXIII.	17	...	LIV.	112	14
XXIV.	22	...	LV.	125	...
XXV.	13	...	LVI.	124	3
XXVI.	9	...	LVII.	130	3
XXVII.	3	...	LVIII.	128	7
XXVIII.	70	...	LIX.	132	7
XXIX.	50	...	1st Index ...	543	2
XXX.	61	2	2nd „ ...	800	...
XXXI.	90	...			

LIBRARY CATALOGUE

... ..

... ..

547

...

In addition to the above volumes of the *Monthly Notices*, the Society has a considerable stock of separate numbers of nearly all the volumes. With the exception, however, of Vols. XXXVI. to LIX., no complete volumes can be formed from the separate numbers in stock.

Celestial Photographs.

The following is a list of reproductions of Celestial Photographs published by the Royal Astronomical Society for sale to the Fellows :—

R.A.S. Ref. No.	Subject.	Photographed by
1	Total Solar Eclipse, 1889 January 1	W. H. Pickering
2	Total Solar Eclipse, 1893 April 16	J. M. Schaeberle
3	Total Solar Eclipse, 1886 August 29	A. Schuster
4	Nebulæ in the <i>Pleiades</i>	Isaac Roberts
5	Nebula M 74 <i>Piscium</i>	Isaac Roberts
6	Great Nebula in <i>Orion</i>	Isaac Roberts
7	Milky Way near M 11	E. E. Barnard
8	Milky Way near Cluster in <i>Perseus</i>	E. E. Barnard
9	Comet <i>c</i> 1893 IV. (Brooks), 1893 October 21	E. E. Barnard
10	Comet <i>a</i> 1892 I. (Swift), 1892 April 7	E. E. Barnard
11	Nebula about η <i>Argûs</i>	David Gill
12	Portion of Moon (Hyginus-Albategnius)	Læwy and Puiseux
13	Comet <i>c</i> 1893 IV. (Brooks), 1893 October 22	E. E. Barnard
14	Comet <i>c</i> 1893 IV. (Brooks), 1893 October 20	E. E. Barnard
15	Comet <i>c</i> 1893 IV. (Brooks), 1893 November 10	E. E. Barnard
16	Comet <i>a</i> 1892 I. (Swift), 1892 April 26	E. E. Barnard
17	Comet <i>f</i> 1892 III. (Holmes), 1892 November 10	E. E. Barnard
18	Comet <i>a</i> 1892 I. (Swift), 1892 April 18	E. E. Barnard
19	Portion of Moon (Alps, Apennines, &c.)	Læwy and Puiseux
20	Nebula in <i>Andromeda</i>	Isaac Roberts
21	<i>Jupiter</i> , 1892 September 26	Lick Observatory
22	Cluster M 13 <i>Herculis</i>	W. E. Wilson
23	Total Solar Eclipse, 1893 April 16 (5 sec.)	J. Kearney
24	Total Solar Eclipse, 1893 April 16 (20 sec.)	J. Kearney
25	The Moon (Age 7 ^d 3 ^h)	Lick Observatory
26	The Moon (Age 12 ^d 6½ ^h)	Lick Observatory
27	The Moon (Age 16 ^d 18 ^h)	Lick Observatory
28	The Moon (Age 23 ^d 8 ^h)	Lick Observatory
29	The Sun, 1892 February 13	Roy. Obs., Greenwich
30	The Sun, 1892 July 8	Roy. Obs., Greenwich
31	Portion of Moon (Region of <i>Maginus</i>)	Læwy and Puiseux
32	The Moon (Age 14 ^d 1 ^h)	Lick Observatory

R.A.S. Ref. No.	Subject.	Photographed by
33	Portion of Moon (Ptolemæus, &c.)	Lick Observatory
34	Portion of Moon (Mare Serenitatis)	Lick Observatory
35	Portion of Moon (Clavius, Licetus, &c.)	Lick Observatory
36	Portion of Moon (Regiomontanus, &c.)	Lick Observatory
37	Portion of Moon (Tycho, Thebit, &c.)	Lick Observatory
38	Portion of Moon (Theophilus, &c.)	Lick Observatory
39	Total Solar Eclipse, 1896 August 9 (3 sec.)	S. Kostinsky
40	Total Solar Eclipse, 1896 August 9 (26 sec.)	A. Hansky
41	Cluster M 56 <i>Lyra</i>	
42	Nebulæ M 81, 82 <i>Ursæ Majoris</i>	
43	Cluster M 56 <i>Lyra</i> (enlarged)	
44	Solar Corona, 1871 December 12, Baikul	H. Davis
45	Solar Corona, 1875 April 6, Siam	Lockyer and Schuster
46	Solar Corona, 1878 July 29, Wyoming	W. Harkness
47	Solar Corona, 1882 May 17, Egypt	Abney and Schuster
48	Solar Corona, 1883 May 6, Caroline Island	Lawrance and Woods
49	Solar Corona, 1885 September 9, Wellington, N.Z.	Radford
50	Solar Corona, 1886 August 29, Grenada, W.I.	A. Schuster
51	Solar Corona, 1887 August 19, Japan	M. Sugiyama
52	Solar Corona, 1889 January 1, California	W. H. Pickering
53	Solar Corona, 1889 December 22, Cayenne	J. M. Schaeberle
54	Solar Corona, 1893 April 16, Fundium	J. Kearney
55	Solar Corona, 1893 April 16, Brazil	A. Taylor
56	Great Nebula in <i>Orion</i>	W. E. Wilson
57	Dumb-bell Nebula, <i>Vulpecula</i>	W. E. Wilson
58	Spiral Nebula, <i>Canes Venatici</i>	W. E. Wilson
59	Spiral Nebula, <i>Canes Venatici</i> (enlarged)	W. E. Wilson
60	Annular Nebula in <i>Lyra</i>	W. E. Wilson
61	Meteor Trail and Comet Brooks, 1893 November 13	E. E. Barnard
62	Total Solar Eclipse, 1898 January 22 (5 sec.)	W. H. M. Christie
63	Total Solar Eclipse, 1898 January 22 (20 sec.)	W. H. M. Christie
64	Solar Corona, 1896 August 9, Novaya Zemlya	G. Baden-Powell
65	Solar Corona, 1898 January 22, Pulgaon, India	E. H. Hills
66	Nebula in <i>Andromeda</i>	Roy. Obs., Greenwich
67	Spectrum of Sun's limb, 1898 January 22	E. H. Hills
68	Annular Nebula, <i>Lyra</i>	Lick Observatory
69	Dumb-bell Nebula, <i>Vulpecula</i>	Lick Observatory
70	Spiral Nebula, <i>Canes Venatici</i>	Lick Observatory
71	Spiral Nebula, <i>Ursa Major</i>	Lick Observatory

R.A.S. Ref. No.	Subject.	Photographed by
72	Trifid Nebula, <i>Sagittarius</i>	Lick Observatory
73	Great Nebula in <i>Orion</i>	Lick Observatory
74	Cluster M 13 <i>Herculis</i>	Lick Observatory
75	Solar Surface with Faculae	G. E. Hale
76	Faculae and Prominences	G. E. Hale
77	Total Solar Eclipse, 1898 Jan. 22 ($\frac{2}{3}$ sec.)	W. H. M. Christie
78	Nebula H V. 14 <i>Cygni</i>	W. E. Wilson

Nos. 44-55 and Nos. 64 and 65 form a series of corona photographs, oriented and reduced to the same scale.

The above photographs are now on sale to Fellows as prints, either platinotype or aristotype, mounted on sunk cut-out mounts, measuring 12 inches by 10 inches, and also as lantern slides. Nos. 44-55 and Nos. 64 and 65 are also supplied as transparencies, $6\frac{1}{4}$ inches square.

Price of prints, 1s. 6d. each; lantern slides, 1s. each; packing and postage extra.

Unmounted prints, 1s. each, can be obtained to order.

Transparencies, $6\frac{1}{4}$ inches square (Nos. 44-55 and Nos. 64 and 65), 3s. 6d. each.

Orders to be addressed to W. H. Wesley, Burlington House, London, W. In ordering prints or slides the R.A.S. Reference No. only need be quoted, but in the case of prints it should be stated whether platinotypes or aristotypes are required.

Instruments belonging to the Society.

A brief description of the chief instruments and other particulars relating to them will be found in *Monthly Notices*, vol. xxxvi. p. 126.

- No. 1. The *Harrison* clock.
- „ 2. The *Owen* portable circles, by Jones.
- „ 3. The *Beaufoy* circle.
- „ 4. The *Beaufoy* transit instrument.
- „ 5. The *Herschel* 7-foot telescope.
- „ 6. The *Greig* universal instrument, by Reichenbach and Ertel. The transit telescope, by Utzschneider and Fraunhofer, of Munich.
- „ 7. The *Smeaton* equatorial.
- „ 8. The *Cavendish* apparatus.
- „ 9. The 7-foot Gregorian telescope (late Mr. Shearman's).
- „ 10. The variation transit instrument (late Mr. Shearman's).
- „ 11. The universal quadrat, by Abraham Sharp.

No. 12. The *Fuller* theodolite.

„ 13. The standard scale, by Troughton and Simms.

„ 14. The *Beaufoy* clock, No. 1.

„ 15. The *Beaufoy* clock, No. 2.

„ 16. The *Wollaston* telescope.

„ 17. The *Lee* circle.

„ 18. The *Sharpe* reflecting circle.

„ 19. The *Brisbane* circle.

„ 20. The *Baker* universal equatorial.

„ 21. The *Reade* transit.

„ 22. The *Matthew* equatorial, by Cooke.

„ 23. The *Matthew* transit instrument.

„ 24. The *South* transit instrument.

„ 25. A sextant, by Bird (formerly belonging to Captain Cook).

„ 26. A globe showing the precession of the equinoxes.

The *Sheepshanks* collection :—

„ 27. (1) 30-inch transit instrument, by Simms, with level and two iron stands.

„ 28. (2) 6-inch transit theodolite, with circles divided on silver; reading microscopes, both for altitude and azimuth; cross and siding levels; magnetic needle; plumb-line; portable clamping foot and tripod stand.

„ 29. (3) Equatorial stand and clock movement for $4\frac{6}{10}$ -inch telescope (telescope lost); double-image micrometer; two wire micrometers; object-glass micrometer.

„ 30. (4) $3\frac{1}{4}$ -inch achromatic telescope, with equatorial stand; double-image micrometer; one terrestrial and three astronomical eyepieces.

„ 31. (5) $2\frac{3}{4}$ -inch achromatic telescope, with stand; one terrestrial and three astronomical eyepieces.

„ 33. (7) 2-foot navy telescope.

„ 34. (8) Transit instrument of 45 inches focal length, with iron stand and also Y's for fixing to stone piers; two axis levels.

„ 35. (9) Repeating theodolite, by Ertel, with folding tripod stand.

„ 36. (10) 8-inch pillar sextant, by Troughton, divided on platinum, with counterpoise stand and artificial horizon.

„ 37. (11) Portable zenith telescope and stand, $2\frac{3}{4}$ -inch aperture and 26 inches focal length; 10-inch horizontal circle and 8-inch vertical circle, reading to $10''$ by two verniers to each circle.

„ 38. (12) 18-inch Borda repeating circle, by Troughton, $2\frac{1}{8}$ -inch aperture and 24 inches focal length; the circles divided on silver, the horizontal circle being read by four verniers, and the vertical circle by three verniers, each to $10''$.

„ 39. (13) 8-inch vertical repeating circle, with diagonal telescope,

- by Troughton and Simms; circle divided on silver, reading to $10''$; a 5-inch circle at eye-end, reading to single minutes; horizontal circle 9 inches diameter in brass to single minutes.
- No. 40. (14) A set of surveying instruments, consisting of a 12-inch theodolite for horizontal angles only, reading to $10''$; two sets of adjusting plates; tripod stand with enclosed telescope; heavy stand for theodolite; Y-piece of level; two large and three small ground-glass bubbles divided; level collimator, object-glass $1\frac{1}{2}$ -inch diameter and 16 inches focal length; micrometer eyepiece, comb, and wires; mercury bottle and trough.
- „ 41. (15) Level collimator, with object-glass $1\frac{1}{2}$ -inch diameter and 16 inches focal length; stand, rider-level, and fittings.
- „ 42. (16) 10-inch reflecting circle by Troughton, reading by three verniers to $20''$; counterpoise stand; artificial horizon, with mercury; two tripod stands.
- „ 43. (17) Hassler's reflecting circle, by Troughton, with counterpoise stand.
- „ 44. (18) 6-inch reflecting and repeating circle, by Troughton and Simms, contained in three boxes, two of which form stands. Circle divided on silver, reading to single minutes; two inside arcs divided to single degrees, 150 degrees on each side; artificial horizon and mercury.
- „ 45. (19) 5-inch reflecting and repeating circle, by Lenoir, of Paris.
- „ 46. (20) Reflecting circle, by Jecker, of Paris, 11 inches in diameter, with one vernier reading to $15''$.
- „ 47. (21) Box sextant; reflecting plane and level.
- „ 48. (22) Prismatic compass, by Troughton and Simms.
- „ 49. (23) Mountain barometer.
- „ 50. (24) Prismatic compass, by Thomas Jones, mounted with a cylindrical lens.
- „ 51. (25) Ordinary $4\frac{1}{2}$ -inch compass with needle.
- „ 52. (26) Dipping needle, by Robinson.
- „ 53. (27) Compass needle, mounted for variation.
- „ 54. (28) Magnetic intensity needle, by Meyerstein, of Göttingen; a strongly fitted brass box with heavy magnet; filar suspension.
- „ 55. (29) Box of magnetic apparatus.
- „ 56. (30) Hassler's reflecting circle, by Troughton; a $10\frac{1}{2}$ -inch reflecting and repeating circle, with stand and counterpoise, divided on platinum with two movable and two fixed indices; four verniers reading to $10''$.
- „ 57. (31) Box sextant and glass plane artificial horizon, by Troughton and Simms.
- „ 58. (32) Plane $2\frac{3}{8}$ -inch speculum, artificial horizon and stand.
- „ 59. (33) $2\frac{1}{2}$ -inch circular level horizon, by Dollond.

- No. 60. (34) Artificial horizon, roof, and trough ; the trough $8\frac{1}{4}$ by $4\frac{1}{2}$ inches ; tripod stand.
- „ 61. (35) Set of drawing instruments, consisting of 6-inch circular protractor and common protractor, T-square ; one beam compass.
- „ 62. (36) A pantograph.
- „ 63. (37) A noddy.
- „ 64. (38) A small Galilean telescope with object-glass of rock crystal.
- „ 65. (39) Five levels.
- „ 66. (40) 18-inch celestial globe.
- „ 67. (41) Varley stand for telescope.
- „ 69. (43) Telescope, with object-glass of rock crystal.
- „ 71. Portable altazimuth tripod.
- „ 72. Four polarimeters.
- „ 74. Registering spectroscope, with one large prism.
- „ 76. Two five-prism direct-vision spectroscopes.
- „ 78. $9\frac{1}{4}$ -inch silvered-glass reflector and stand, by Browning.
- „ 79. Spectroscope.
- „ 80. A small box, containing three square-headed Nicol's prisms ; two Babinet's compensators ; two double-image prisms ; three Savarts ; one positive eyepiece, with Nicol's prism ; one dark wedge.
- „ 81. A back-staff, or Davis' quadrant.
- „ 82. A nocturnal or star dial.
- „ 83. An early non-achromatic telescope, of about 3 feet focal length, in oak tube, by Samuel Scatliffe, London.
- „ 84. A Hollis observing chair.
- „ 85. Double-image micrometer, by Troughton and Simms.
- „ 86. $4\frac{1}{2}$ -inch Gregorian reflecting telescope, by Short, with altazimuth stand and 6-inch altitude and azimuth circles and two eyepieces.
- „ 87. $3\frac{1}{4}$ -inch Gregorian reflecting telescope with wooden tripod stand.
- „ 88. Pendulum, with 5-foot brass suspension rod, working on knife-edges, by Thomas Jones.
- „ 89. A Rhabdological Abacus. A contrivance invented by Mr. H. Goodwyn, consisting of a box filled with compartments, in which are square rods covered with numbers, which can be arranged so as to facilitate the labour of multiplying high numbers.
- „ 90. An Arabic celestial globe of bronze, $5\frac{3}{4}$ inches in diameter.
- „ 91. Astronomical time watch-case, by Professor Chevallier.
- „ 92. 2-foot protractor, with two movable arms, and vernier.
- „ 93. Beam compass, in box.
- „ 94. 2-foot navigation scale.
- „ 95. Stand for testing measures of length.
- „ 96. Artificial planet and star, for testing the measurement of a fixed distance at different position angles.

- No. 97. 12-cell Leclanché battery.
- „ 98. 2-foot 6-inch navy telescope, with object glass $2\frac{1}{2}$ inches, by Cooke, with portable wooden tripod stand.
- „ 99. 12-inch transit instrument, by Fayrer and Son, with level and portable stand.
- „ 100. 9-inch transit instrument, with level and iron stand.
- „ 101. Small equatorial sight instrument, by G. Adams, London.
- „ 102. Sun-dial, by Troughton.
- „ 103. Sun-dial, by Casella.
- „ 104. Sun-dial.
- „ 105. Box sextant, by Troughton and Simms.
- „ 106. Prismatic compass, by Schmalcalder, London.
- „ 107. Compass, by C. Earle, Melbourne.
- „ 108. Prismatic compass, by Negretti and Zambra.
- „ 109. Dipleidoscope, by E. Dent.
- „ 110. Abney level, by Elliott.
- „ 111. Pocket spectroscope, by Browning.
- „ 112. Universal sun dial.
- „ 113. Double sextant, by Jones.
- „ 114. Two models, illustrating the effects of circular motions.
- „ 115. A cometarium.
- „ 117. Two old sun dials.
- „ 118. A $10\frac{1}{2}$ -inch sixteenth-century celestial globe, on bronze tripod stand.
- „ 119. Specimens of diffraction gratings, by Prof. W. A. Rogers.
- „ 120. A 6-prism spectroscope, by Browning.
- „ 121. Spitta's improved maximum and minimum thermometer.
- „ 122. A 6-inch speculum, with flat; the speculum said to be by Sir W. Herschel, and re-figured by Sir J. Herschel.
- „ 123. A 6-inch refracting telescope, by Grubb, with 3 eye-pieces.
- „ 124. Position micrometer, by Cooke.
- „ 125. A 6-inch refracting telescope, by Simms, with eyepieces and solar diagonal.
- „ 126. $3\frac{1}{2}$ -inch portable refracting telescope, by Tulley, with tripod stand.
- „ 127. Globe representing the visible surface of the Moon, by John Russell, R.A. (1797).
- „ 128. Bichromate battery and Ruhmkorff coil.
- „ 129. Slater's improved armillary sphere.
- „ 130. 10-inch brass pillar sextant with counterpoise stand, by Troughton.
- „ 131. Double box sextant, by Cary.
- „ 132. Equatorially mounted camera with $2\frac{1}{2}$ -inch portrait lens and telephotographic enlarging lens by Dallmeyer; iron pillar. [Presented by the executors of the late Sidney Waters.]
- „ 133. $3\frac{1}{4}$ -inch equatorial by Ross, with tall tripod stand, equa-

torial mounting, eyepieces, and micrometer. [Presented by Mrs. Mann.]

No. 134. Old transit instrument, 2-inch aperture and 3-feet focal length, formerly belonging to Dr. Longfield, of Cork. [Presented by the executors of the late R. J. Lecky.]

„ 135. Globe of Mars, by E. M. Antoniadi. [Presented by M. Antoniadi.]

Besides the above, there is the following apparatus available for eclipse work :—

4 Slits for spectroscope.

2 Abney lenses used in photographing the corona.

2 Dallmeyer negative enlarging lenses.

1 Cœlostast with 16-inch plane mirror.

The following instruments are lent, during the pleasure of the Council, to the undermentioned persons :—

No. 4. The *Beaufoy* transit instrument, to the Observatory, Kingston, Canada.

„ 16. The *Wollaston* telescope, to Mr. R. Inwards.

„ 23. The *Matthew* transit, to Captain W. Noble.

„ 28. (2) 6-inch theodolite and stand, to Dr. A. A. Common.

„ 29. (3) Equatorial mounting, clock, &c., to the Rev. C. D. P. Davies.

„ „ Wire micrometer (No. 2), to the Rev. C. D. P. Davies.

„ 30. (4) $3\frac{1}{4}$ -inch equatorial and stand, to Mr. C. H. Johns.

„ „ Double-image micrometer, to the Rev. W. J. B. Roome.

„ 50. (24) Prismatic compass, to Mr. Maxwell Hall.

„ 57. (31) Box sextant, to Dr. A. A. Common.

„ 69. (43) Telescope with rock-crystal object glass, to Sir W. Huggins.

„ 72. (c) Polarimeter, to Professor C. Michie Smith.

„ 74. Registering spectroscope, to Mr. Shackleton.

„ 78. $9\frac{1}{4}$ -inch reflector and stand, to the Rev. W. J. B. Roome.

„ 98. 2-ft. 6-in. navy telescope, to the Rev. J. M. Bacon.

„ 120. 6-prism spectroscope by Browning, to Mr. E. B. Knobel.

„ 123. 6-inch telescope, by Grubb (object-glass only), to Mr. W. E. Wilson.

„ 125. 6-inch refractor, by Simms, to Dr. A. A. Common.

„ 128. Bichromate battery, to the Rev. W. J. B. Roome.

„ 132. The *Waters* equatorial, to Mr. E. W. Maunder.

„ 133. $3\frac{1}{4}$ -in. equatorial, by Ross, to Mr. A. W. Roberts.

The Gold Medal.

The Council have awarded the Society's Gold Medal to M. Henri Poincaré, for his researches in celestial mechanics. The President will lay before the Society the grounds upon which the award has been founded.

Publications of the Society.

Vols. LII. and LIII. of the *Memoirs* have been published during the year.

Vol. LII. consists entirely of "Observations of twenty-three Variable Stars" by the late Mr. George Knott, and was edited by Professor H. H. Turner. The Council have pleasure in expressing their indebtedness to Mrs. Knott for her generous contribution towards the expenses of publication of these observations.

Vol. LIII. contains the following papers :—

Observations of the Solar Eclipse, 1896 August 8, by E. J. Stone.

Micrometrical measures of Double Stars, by W. Coleman.

Theory of the Motion of the Moon, chapters i-v., by Ernest W. Brown.

Determination of Terrestrial Longitudes by Photography, by Capt. E. H. Hills.

New values of the division errors of the Greenwich Transit Circle, by F. W. Dyson and W. G. Thackeray.

General Catalogue of the Radiant Points of Meteoric Showers, by W. F. Denning.

Double Star observations, 1895-98, by W. H. Maw.

Supplementary Library Catalogue.

A supplementary catalogue of the Library has been prepared by the Assistant Secretary, which is now in the press, and will shortly be in the hands of the Fellows.

OBITUARY.

The Council regret that they have to record the loss by death of the following Fellows during the past year :—

Lieut. C. W. Baillie.
Rev. E. L. Berthon.
James Carpenter.
Samuel Cooke.
Thomas Finch.
N. E. Green.
John Marshall.
B. T. Moore.
John Newton.
G. C. Pulsford.
J. C. Roger.
Rev. John Slatton.
Hale Wortham.

The Council have received notice of the death of Thomas Finch, which occurred in 1896.

CHARLES WILLIAM BAILLIE was born at Greenwich 1844 June 26, and was the son of the late Henry Robert Baillie, of Queen's Home, Greenwich Hospital, and grandson of the late Jonathan Baillie, Paymaster R.N. He entered the Navy in 1859, obtained his commission as navigating sub-lieutenant in 1864, and was promoted to navigating lieutenant in 1870. He was detailed on surveying duties in various parts of the world, and in 1870 he became a first-class assistant surveyor. Whilst he was on the North American station, about 1871, he invented his sounding machine, which is still in use. It is a modification of the apparatus known as the "Hydra" machine, so named because it was constructed by the blacksmith on H.M.S. *Hydra*. It was used in the *Challenger* expedition, and is described in Sir Wyville Thomson's *Cruise of H.M.S. "Challenger."* Whilst Lieutenant Baillie was surveying on the China station on board the *Sylvia*, under Captain (now Vice-Admiral) St. John, he was appointed Director of Naval Studies at the Imperial Naval College at Tokio, Japan, an office which he held during the years 1873-79. It was probably in these years that he picked up the ancient Japanese works on Astronomy, which he presented in 1894 to the Society. In 1879 he was placed on the retired list, and became Assistant Marine Superintendent at the Meteorological

Office ; on the retirement of Captain Toynbee in 1888, he succeeded him as Marine Superintendent. The principal works which he has carried out in that capacity have been the charts of sea surface temperature, of barometrical pressure, and of currents for all oceans. The discussion of the meteorology of the South Indian Ocean from the Cape of Good Hope to New Zealand, which is shortly about to appear, has been carried out under Lieutenant Baillie's superintendence, while he had laid down the lines of inquiry to be pursued in the work now in hand at the office—the *Meteorology of the South Atlantic and of the Coasts of South America*.

Lieutenant Baillie married in 1867 Helen, daughter of A. M. Conyers, of Bermuda. He died suddenly at Broadstairs, 1899 June 24, at the age of fifty-five years, leaving a widow and seven children.

He was elected a Fellow of this Society 1879 January 10.

THE REV. EDWARD LYON BERTHON was born in Finsbury Square, London, 1813 February 20. His father, Peter Berthon, was a descendant of St. Pol le Berthon, only son of the Huguenot Marquis de Chatelléraut, who survived the massacre that followed the revocation of the Edict of Nantes in A.D. 1685, and escaped to Bordeaux, thence to Lisbon, where he engaged in trade as a merchant, and had contracts for supplying the Army with provisions during all the campaigns in the Peninsula. His mother was a daughter of the great surgeon, Henry Park, of Liverpool.

When only five years of age he was adopted by his grandmother, who resided at Leyton, in Essex ; and he was sent to private schools at Walthamstow and Woodford until he was nearly fourteen years of age. About this time his grandfather, Henry Park, was retiring after a very successful practice of sixty years, making over the same to a Mr. James Dawson, on the understanding that it was eventually to come into the possession of his grandson. Accordingly Edward Lyon went in 1828 to Liverpool, where, during a period of five years, he spent the greater part of every day at the principal hospital, under James Dawson, who was then chief surgeon of that institution. He early showed a strong predilection for mechanical science. He had stood by George Stephenson when he started the "Rocket" on the first mile of railway at Rainhill, and now would seize every opportunity of getting to the Phoenix Foundry, in which two of his brothers-in-law were partners, and where, encouraged in his attempts, he was told that "he was much too good for a doctor, and that he ought to be an engineer." However, after five years' study at Liverpool, he went to Dublin, and completed his medical course at the College of Surgeons in that city.

In 1834 he married Margaret, youngest daughter of William Preston, Esq., of Birchfield and Fairview, Toxteth Park, Liverpool, by whom he had two sons and five daughters. One son and four daughters survive him. Mrs. Berthon died in 1865.

After his marriage Mr. Berthon spent considerable time both in home and continental travel, and in 1841 he determined to take Holy Orders. He had, three years previously, entered his name at Emmanuel College, Cambridge, but migrated to Magdalene, where he entered as a Fellow Commoner. He took his degree in 1845, and, having been ordained deacon, was licensed to the curacy of Lymington, in Hampshire. In 1846 he was ordained priest, and in the following year was presented to the living of Holy Trinity, Fareham, in the same county.

It was during his residence at Fareham—a country town then largely the abode of retired naval officers—that he conceived the idea of his collapsible boat. This invention, which has made his name famous, was suggested by the wreck of the s.s. *Orion* off the coast of Portpatrick, 1849 June 29. He also at this time perfected his “speed indicator” or “perpetual log” for ships, which was fitted to the then new royal yacht *Victoria and Albert*; also to the *Osborne*. In or about 1858 he resigned his living, as he said, “to get away from ships and boats.” In 1860 he became Vicar of Romsey, Hants, which he held for thirty-two years, retiring in 1892.

About twenty-seven years ago (1873), at the earnest solicitation of the late Samuel Plimsoll, M.P., the collapsible boat was revived. Another start was made. Fortune favoured the enterprise; large orders came in from our own and the German Governments; and under the style and title of the “Berthon Boat Co., Ltd.,” with Mr. Berthon as constructing director, and his son, E. P. Berthon, as manager, it soon became a thriving industry, employing nearly one hundred workmen. Mr. Berthon gave a lecture in this connection at the Royal United Service Institution so recently as 1895, his subject being “Collapsible Boats and Pontoons for Military Purposes.” Mr. Berthon was among those who in early days foresaw the future of the screw propeller for ships (1835), but, through many discouragements, he abandoned a patent which he had taken out. He was told that the screw was “a pretty toy which never would and never could propel a ship.” He had only to wait until the close of the Crimean war to see, as he would say, “every line of battleship, every frigate, sloop of war, floating battery, and gunboat *with the screw*.” He also invented the “Nautachometer,” or speed indicator; the clinometer, or trim indicator; roll and draft indicator; drogue, or sea-anchor; collapsible pontoons, portable hospitals, tents, &c. Mr. Berthon was, in short, a man of wonderful versatility. As a preacher he was eloquent, as a lecturer bright and entertaining. Moreover, he had a great charm of speech, and was master of three or four languages. Theology, architecture, philosophy, mechanics, sculpture, and art, in all he excelled, and many are the traces of his handiwork, in cunningly carved and leafy boss, in gilt pateræ, and sacred symbol, to be found in the grand old Norman Abbey Church at Romsey, where, notwithstanding his retirement, he did frequent duty, and was to the

last the authority to whom all referred in matters connected with the restoration of that noble fabric.

He designed the well-known "Romsey Observatory"; two or three equatorial stands for reflecting and refracting telescopes, one of which—a 12½-inch reflector—received a silver medal at the Paris Exhibition, 1878. His "dynamometer" for ascertaining the power of eyepieces is well known, though not so much so his latest proposal—of only last year—for standardising eyepieces. Many telescopes were constructed by him of different apertures—the specula, the writer believes, excepted—including a reflector of 18 inches, and weighing nearly two tons, for the late Rev. H. Cooper-Key; a 10·5-inch equatorial for the late Professor Pritchard of Oxford, and a stand for that "keen observer of the starry host" and author of *Celestial Objects*, the Rev. Thomas Webb, of Hardwick Vicarage, Hereford. And of work in other directions, "it is a pleasure," said he, "to reflect that I have enabled many a brother priest of limited means to rejoice in the possession of an equatorial telescope of from nine to eighteen inches aperture, and thus to pursue the most noble of the physical sciences, and to sing intelligently with the Psalmist, 'Cœli enarrant gloriam Dei.'"

In the autumn of 1898 Mr. Berthon finished an equatorial of sixteen and a half inches aperture (speculum by Sir Howard Grubb) and nearly ten feet focal length, together with an observatory, constructed at the Boat Works, Romsey, for a gentleman at Johannesburg.

Mr. Berthon was elected a Fellow of this Society 1865 January 8, and retired in 1880. He had one paper in the *Monthly Notices*—"On the Equestrian Equatorial" (*M.N.* vol. xxxv. p. 106). It was read at the meeting 1874 December 11, when he exhibited the instrument. He was re-elected 1899 May 12, and many will remember the ovation he received when, on his re-admission 1899 June 9, he exhibited two telescopes of his construction, together with a simple device for dividing telescope circles.

Mr. Berthon died at his residence, St. Margaret's, Cupernham, Romsey, 1899 October 28.

[For the above particulars the Council is indebted to Mr. J. J. Hall, of Slough.]

JAMES CARPENTER was born at Greenwich in the year 1840. He entered the Magnetical and Meteorological Department of the Royal Observatory, Greenwich, as computer, in the year 1854, being after a time transferred in a similar capacity to the Astronomical Department, in which, on the retirement of Mr. H. Breen, in 1859, he was appointed assistant. At this time the new South East Equatorial was approaching completion, and in 1861 it was placed under his special charge. He was a good draughtsman, and, in addition to his ordinary astronomical duties, made from time to time drawings of the planets *Mars*, *Jupiter*,

and *Saturn*, one also of the nebula in Orion, some of the lunar crater *Linné* (then suspected of having changed its form), as well as drawings of various comets, including some excellent pictures of Donati's comet (1858) and of the Comet II., 1861 (the great comet of the summer of that year). In the year 1863 he measured the positions of lines in the spectra of numerous stars with the instrument designed by Sir George Airy. He had the continuous charge of the library and manuscripts of the Observatory, and prepared an entirely new catalogue, on the slip system, of the books of the former. He was elected a Fellow of the Society 1867 February 8. In 1870, at the request of Sir William Huggins, and with the consent of the Astronomer Royal and the Admiralty, he went to Oran, in Algeria, to observe the total solar eclipse of December 22 of that year, but the circumstances of weather were unfortunately unfavourable. In 1871 he carried out, under the direction of the Astronomer Royal, a series of experiments for determining the distribution of magnetism in bar magnets and in galvanic coils, and in 1872 was deputed, in conjunction with Captain Tupman, R.M.A., to make an examination into the magnetic condition of the Britannia and Conway tubular iron bridges, the results of these experiments being contained in two papers contributed by Sir George Airy to the Royal Society in the year 1872. In the same year Mr. Carpenter resigned his position at the Royal Observatory to enter the service of John Penn & Sons, marine engineers. He had previously married Ellen Penn, the daughter of the late Mr. Thomas Penn of the same firm. After holding the position mentioned for eighteen years, he was led to retire therefrom on account of the ill health of his wife, who died soon afterwards at Hastings. Mr. Carpenter survived her for nine years, during the later portion of which he suffered from an affection of the heart, from which he died, 1899 October 17, at the age of fifty-nine, at Grove House, Lewisham, leaving no family.

It should be mentioned that Mr. Carpenter worked as collaborator with Mr. James Nasmyth, the engineer, in the preparation of their joint work on "*The Moon*," of which several editions were issued. The authors remark that much labour had been bestowed upon the topography of the Moon, and sufficient written for those who desire acquaintance with the intricate movements of the Moon in space, but that little attention had been given to the Moon's physiography, to the causes of the features, broad and detailed, that our satellite presents. From carefully made drawings of many different portions of the Moon's surface, again and again revised and compared with the actual objects, the authors constructed models which, when placed in the Sun's rays so as faithfully to reproduce the lunar effects of light and shadow, were photographed, thus obtaining pictures representing in a striking manner the details of the lunar surface. In the accompanying text these features of the Moon are described, and the views of the authors as to their formation explained.

Mr. Carpenter was a ready writer, and contributed numerous articles on a variety of subjects, mainly scientific, to the current periodicals of the time; his expositions of phenomena were couched in a style that was not only in itself attractive, but also conveyed to the reader such accurate information as would enable him clearly to understand the various matters treated. He had also a very practical turn of mind, was a good mechanic, had artistic tastes and musical ability, and was moreover an excellent photographer, and in the later years of his life he gave great assistance, in conjunction with Dr. Moore, in the installation and practical application of the Röntgen ray method to surgical purposes at the Miller Hospital, Greenwich, of which Institution he was a Member of Committee.

W. E.

SAMUEL COOKE was born 1844 May 22. He was educated at Trinity College, Dublin; and, having completed the course in the School of Engineering, he took his degree in 1868, receiving two special certificates in Mechanical and Physical Science, and in Chemistry, Geology, and Mining. Immediately after taking his degree, he was appointed to be Professor of Chemistry and Geology in the Civil Engineering College at Poona, University of Bombay. His father, Mr. Theodore Cooke, was at the time Principal of the College; and on his retirement in 1893, after holding the office of Principal for twenty-eight years, the son, Mr. Samuel Cooke, was appointed Principal of the College of Science, as it was then called, in his stead. Mr. Cooke was the author of several text-books, which have run through many editions; amongst others may be mentioned his *First Principles of Chemistry* (six editions), *Students' Practical Chemistry* (three editions), *First Principles of Astronomy* (five editions), *The Foundations of Scientific Agriculture*, published in 1897.

He was elected a Fellow of this Society in 1898 February 11.

NATHANIEL EVERETT GREEN was born at Bristol 1823 August 21. He was the third son of Benjamin Holder Green, of that city, and bore his mother's maiden name. She was Elizabeth Everett, of Crockerton, Wilts. He was educated chiefly by his uncle, the Rev. C. Everett, and in 1840 started life in a merchant's office in Liverpool. Finding a commercial life uncongenial to him, and having a great taste for drawing, he decided to adopt art as his profession, and came to London in 1844, entering the Royal Academy as a student in December of that year. Here he worked side by side with Leighton, Millais, and Rossetti. In 1847 he married Elizabeth Goold, of Cork, and after living for about a year in the west of London he eventually settled in St. John's Wood, where he resided for forty-nine years, attracted to the neighbourhood by its quiet retirement and its favourable surroundings for the pursuit of his artistic and astronomical studies. He frequently exhibited his work, both in oil and water colours, at the Royal Academy and other galleries, but the

pressing needs of a large and growing family—he had five daughters and four sons—led him to adopt teaching as a profession. In this he was eminently successful, and gained a widespread reputation. In 1880 he was called to Balmoral, and had the honour of numbering amongst his pupils Her Majesty the Queen, the Princess of Wales, and Princess Beatrice. He was the author of many works on art, principally manuals and other works of a practical kind, which have had a wide circulation.

In 1884 he visited Palestine, and there some of his best water-colour drawings were made. A succession of dreary winters in London drove him in 1890 to seek summer skies for his artistic work, and for this cause, as well as for the benefit of his wife's health, he selected Cannes as his winter home. During the six seasons spent there he formed a wide circle of friends, and he continued his work there till his last visit in 1898–99.

His interest in astronomy dates back to 1859, when he constructed a telescope for himself, and began the long series of observations and drawings which he continued to make till within a year and a half of his death. His most numerous drawings were made in the two observatories in his garden in Circus Road, St. John's Wood. He frequently changed his instruments, always striving to get greater perfection, and in his Memoir on Jupiter (*Memoirs R.A.S.*, vol. xlix.) he speaks of having used five different instruments in his observations during the years 1859–87—namely, successively “a 4-inch and a 5-inch refractor, and reflectors of 9, 13 and 18 inches, the last a superb mirror figured by George With, of Hereford.” In 1877, on the occasion of the favourable opposition of *Mars*, Mr. Green went to Madeira, and during August and September he made the series of admirable drawings of the planet with which his name will always be associated. Of the forty one sketches made with a 13-inch With reflector, twelve were reproduced in his Memoir (*Memoirs R.A.S.*, vol. xlv.), as well as enlarged drawings of the south polar cap and a map of the planet. Of these drawings Professor Keeler has said in his Memoir (*Memoirs R.A.S.*, vol. li.): “The admirable drawings of Mr. Green owe much of their value to the care which has been bestowed on the appearance of the different features, and their general agreement with views of *Mars* in both large and small telescopes is doubtless due to the same reason. It seems to me that the habit of representing indefinite boundaries by sharp lines and neglect to preserve a uniform scale of relative intensity are responsible for most of the discrepancies in drawings which are ascribed to personality of the observer in interpreting faint markings.” It is interesting to note that Mr. Green's observations were made with a 13-inch reflector, and Professor Keeler's with the 13-inch refractor of the Allegheny observatory.

At the less favourable opposition of *Mars* in 1886, Mr. Green made further studies of the planet, and made a map of the northern hemisphere. These were not published, but several of

the sketches and a map of the planet constructed from them are in the rooms of the Society.

In the *Monthly Notices* of the Society six short papers by Mr. Green are published relating to observations of *Mars* and *Saturn*. And the *Memoirs* of the Society contain two papers by him; the first in vol. xlv., already referred to as containing the results of his observations of *Mars* in 1877; the other, in vol. xlix., giving the results of a series of observations of *Jupiter* during the years 1859-87, and illustrated by a series of beautiful drawings.

In the Journal of the Selenographical Society Mr. Green has given proof of his active membership in a long series of papers on Lunar formations, accompanied by drawings.

Mr. Green was a member of the Provisional Committee of the British Astronomical Association, and was President of the Association in 1897-98. In 1896 he joined the Eclipse expedition to Norway, and it is much to be regretted that he had not the opportunity of using his skill in the delineation of the corona. He was a type of the best kind of amateur observer. Possessing great skill in drawing, he devoted himself to observations in which his keen sight and true hand enabled him to secure results of permanent value. He was always ready to put his experience at the disposal of other observers, a fact which is exemplified both in the character of his notes, already referred to, in the *Monthly Notices* and in the admirable practical lecture on astronomical drawing published in the third volume of the *Journal of the British Astronomical Association*.

For a period of nearly forty years he continued his astronomical work with unflagging perseverance. His profession often claimed him the whole day long, and after a light meal he would begin work with the telescope, often prolonging his study far into the night. On unfavourable evenings he would devote himself with equal assiduity to work with the microscope.

Besides his published drawings, Mr. Green left behind him a great number of sketches of detail on the Moon, of *Saturn* and of *Mars*, and a long series of drawings of *Jupiter*.

He was elected a Fellow of the Society 1875 February 12. He died after a very short illness, 1899 November 10, at the age of seventy-six, leaving a widow.

[For most of the particulars in this notice the Council is indebted to his daughter, Miss Green.]

JOHN MARSHALL was born at Leeds 1825 April 11, and was the son of Thomas Marshall. He got a training in lithography, and was for some years the manager of one of the large printing works in Leeds. Whilst he was engaged in lithography he drew upon stone facsimiles of many letters of eminent writers, and they were printed on a large sheet. A bronze medal was awarded to him for this holograph sheet at the Leeds Exhibition of 1858. For twenty-two years Mr. Marshall was Secre-

tary and Librarian to the Leeds Church Institute, and retired from this post in 1897 in consequence of ill health. He was an active Freemason, and was a fellow of several of the learned societies.

He was twice married, first in 1846 and again in 1863. By each marriage there were five children. He died in 1899 January 21, leaving a widow and three sons and two daughters.

He was elected a Fellow of this Society 1879 February 14.

[For the above particulars the Council is indebted to his son, Mr. G. H. Marshall, of Leeds.]

BENJAMIN THEOPHILUS MOORE was born 1830 January 3. He went to Cambridge in 1851, entering Pembroke College, and graduated in 1856 as eighth wrangler. He was soon afterwards elected a Fellow of his College, and retained his fellowship until 1866. On leaving Cambridge in 1856 Mr. Moore became Mathematical Master of the Army Class at Harrow, and in 1859 he was appointed Professor of Mathematics at the Royal Staff College, Sandhurst, where he remained for five years. Among his pupils in those years may be mentioned Sir W. Palliser and the late General Colley. For several years after 1864 Mr. Moore was occupied in Civil Engineering, and in 1868 he was elected Professor of Civil Engineering and Applied Mechanics in University College, London, a post which he held until the session 1870-71.

In private life Mr. Moore's greatest pleasure was the study of astronomy; he possessed a fine telescope (7-inch object glass) and observatory.

Mr. Moore married in 1872 Margaret Jane, third daughter of Charles John Wood, Esq., J.P., of Glastonbury, Somerset, late of St. Petersburg. He died 1899 November 15, and leaves a widow and five daughters and one son.

He was elected a Fellow of this Society 1893 June 9.

JOHN NEWTON was born at Wickham, Hants, 1832 December 27. He was educated at the Greenwich Hospital Schools under Mr. Edward and Mr. John Riddle, and in 1854 he became a teacher of Navigation and Nautical Astronomy at the Board of Trade Navigation Schools at Leith, and later at Glasgow, and at the Sailors' Home, London. For many years, up to a short time before his death, he conducted a school of his own very successfully. His publications *Newton's Seamanship* and *Newton's Guide to Board of Trade Examinations* were very popular, and passed through many editions.

He was elected a Fellow of this Society 1862 May 9, and died at New Cross 1899 November 10.

[For the above particulars the Council is indebted to his son, Mr. L. B. Newton, of New Cross.]

CHARLES LEESON PRINCE was born at Uckfield, Sussex, 1821 June 15, where he passed the greater portion of his life;

and he died 1899 April 22 at his residence, The Observatory, Crowborough, in the same county, and but seven miles distant from his birthplace.

His father, Charles Prince, originally of Cambridgeshire, settled in Sussex and practised as a medical man in Uckfield and the surrounding districts. From Uckfield to Tunbridge Wells *via* Crowborough, a ride of fourteen miles, was a common professional round in the early part of the century now closing, and Mr. Prince would often relate how his uncle, his father, and another doctor used to meet at Crowborough—then a bare hill-top and not considered safe, being frequented by highwaymen—who on seeing Charles Prince would pounce out and say, "Oh ! it's the doctor ; let him go."

Through his mother, Mary Ann (*née* Boys), Mr. Prince could trace his ancestry to Dean Boys, whose monument may be seen in Canterbury Cathedral.

He was educated primarily at the Uckfield Grammar School, under the Rev. John Underwood, and subsequently at Lewes, and received his medical training at Guy's Hospital like his father before him ; and so became the fifth surgeon in the family by direct descent from father to son. He settled at Uckfield, and practised with his father till the death of the latter, after which he remained in the same place till 1872, when he removed to Crowborough, at that time a barren common, but now, largely through Mr. Prince's influence, a health resort of no small repute. As a physician Mr. Prince paid special attention to the treatment of both epilepsy and hydrophobia. In the British Medical Association's *Journal* of 1874 May 16 appeared an account of his treatment of the latter disease.

Mr. Prince became a member of the Royal College of Surgeons in 1843 ; he was also Licentiate of the Society of Apothecaries ; Fellow of the Royal Astronomical Society (elected 1857) ; Fellow of the Royal Meteorological Society ; Member of the British Astronomical Association ; Member of the Scottish Meteorological Society ; Member of the Selborne Society ; Vice-President of the Tonbridge Wells Photographic Society ; and Member of Council of the Sussex Archæological Society.

He was a man of many parts ; up to his last illness he took a keen and active interest in such widely diverse pursuits as medicine and surgery (though he had retired from practice some ten years), astronomy, meteorology, photography, botany (which he studied practically in his beautiful gardens at Crowborough), archæology and numismatics.

Furthermore he had a very fine library, containing some rare and valuable books, some of the more famous editions of the Bible, and the earliest printed copies of the classics.*

* It will be remembered that in 1898 Mr. Prince presented to the Society a number of very valuable books from his library, including, among others, no less than eight editions of Aratus and three of Manilius.

He was the inventor of "Prince's Perpetual Calendar," by which the day of the week on any date past or future may be found through an arrangement of the Sunday letters. Of this calendar he caused a silver casting to be made, which he left as an heirloom to his infant grandson, Christopher Switzer.

He studied photography practically from the cradle of that science, and has left on record descriptions of many early examples now difficult to procure, and he had a unique collection of old paper negatives dating from the forties. His coins also formed a most interesting collection, well worth studying. His bookplate was a very beautiful production, and may be found in an early number of "Ex Libris."

In 1882 he issued *The Illustrated Account given by Hevelius in his "Machina Celestis" of the Method of Mounting his Telescopes and erecting an Observatory*. This work consists of a reprint of Chapters xviii., xxi., and xxii. from an original copy of Hevelius, together with a translation and some remarks.

In 1883 he published his *Observations upon the Great Comet and Transit of Venus, made at Crowborough, Sussex, in the year 1882*. With illustrations.

And in 1895 he brought out *A Literal Translation of the Astronomy and Meteorology of Aratus, with some Bibliographical Remarks*. With regard to illustrations, Mr. Prince says in the preface to this work: "As a frontispiece to this little volume I have given a representation of the revolution of the planets around their supposed primary, in the order designed to them by the Ancients in the time of Aratus. This engraving appears first, as far as I know, in the edition of Hugo Grotius, publisher at Leyden, in the year 1600; while Cellarius, in his *Harmonia Macrocosmica*, 1661, has given the same on a much larger scale, and it is from this latter plate that I have taken a photograph."

Mr. Prince contributed to the *Monthly Notices* of the Royal Astronomical Society papers on cometary, stellar, and other observations. "He studied the details of the course of discovery in the nature of *Saturn's* ring system, and took part in investigations initiated by Mr. Lynn, which resulted in showing that Cassini and not Ball was the first to detect the principal division in the ring." (See *The Observatory*, 1899 June, pp. 243-4.)

Mr. Prince had several telescopes and other instruments at his observatory which he greatly prized; the chief was an equatorial with an object glass of 6.8 inches aperture and 12 feet focal length, which had formerly belonged to Dr. Pearson, and was originally made by Tulley, about the year 1823 (vide *Memoirs R.A.S.*, vol. ii. p. 507).

His chief contributions to the science of meteorology were his two books on *The Climate of Uckfield and its Neighbourhood*, published in 1871, with a second edition in 1886, and his *Observations upon the Topography and Climate of Crowborough Hill, Sussex*, the second edition of which appeared in 1898, not twelve months before his decease. For more than forty years Mr.

Prince assiduously carried on an unbroken series of meteorological observations.

He married in 1865 Jessie, daughter of the late William Brass, of Clifton, Bristol, and Reigate, who survives him, as likewise do his three children, Ada Charlotte (married to the Rev. B. N. Switzer, M.A., of Hitchin, Herts), William Leeson, and Evelyn.

Mr. Prince's illness became acute in 1898 November, and he underwent a considerable amount of suffering till finally released by his death in 1899 April.

He was buried in Uckfield Churchyard.

[For the above notice the Council is indebted to his son-in-law, the Rev. B. N. Switzer, M.A., of Hitchin.]

GEORGE CARTER PULSFORD was born at Lyme Regis, Dorset, 1842 November 4. He entered the Royal Hospital School, Greenwich, as a pupil in the Upper School in 1852, and thus came first under the care of Dr. Hill, and afterwards studied navigation and astronomy under Mr. John Riddle. At the termination of his school term he was retained as pupil teacher until 1861, when he became Mathematical and Navigation Master on the *Conway* at Liverpool. He, however, remained there but two years, being recalled to his old school as Master in 1863. When in 1874 the Lords Commissioners of the Admiralty decided on educating Naval School Masters at Greenwich, instead of sending them, as formerly, to the Normal Training Colleges, Mr. Pulsford was associated with the Headmaster, Mr. A. Escott, in their training. Finally, on the death of the latter, he succeeded to the Headmastership. Although his special work separated him in a measure from other schools, he always exhibited great interest in educational movements, and was for some time Secretary of the West Kent branch of the Teachers' Guild of Great Britain and Ireland. He was an active Freemason, and was held in high esteem by members of that body. At the time of his death, which occurred on August 1, he was spending his summer vacation at Salcombe.

He was elected a Fellow of this Society 1894 May 11.

T. L.

JAMES CRUIKSHANK ROGER was born at Dundee, 1820 May 21. He was the second son of the late Charles Roger, of Dundee, and was educated at Glasgow University. He resided at Glasgow for some years, and in 1848 married Margaret Chalmers, youngest daughter of Francis Neilson, a physician of that city. Inheriting the literary tastes of his father, he devoted a great deal of his leisure to antiquarian pursuits. During the years 1869-70 he was editor of the *Antiquary*. Heraldry was also a favourite subject with him, and he was the author of *Summary of Moral Evidences*. In one of his earliest works, *Celticism, a Myth*, he upheld the Scandinavian origin of

the British races. After the death of his wife in 1861 he went to London, and entering as a student of the Middle Temple in 1868, he was called to the Bar in 1871. He was a man of considerable energy of character, and for some time was Captain in the 48th Middlesex Rifle Volunteers. He died after three days' illness of acute pneumonia, at his residence, Friars Watch, Walthamstow. His second wife survives him.

He was elected a Fellow of this Society 1887 January 14.

JOHN SLATTER was born at Iffley, near Oxford, 1817 April 9. He went up to Oxford in 1835, and entering at Lincoln College, he became one of Lord Crewe's Exhibitioners and graduated in 1838, taking a third class in Lit. Hum. and a first class in mathematics. In 1841 he took his M.A. degree and was ordained. For some years he worked at Leeds under Dr. Hook, the Vicar of Leeds. He then had charge of Sandford-on-Thames, near Oxford, during the years 1852-61, residing at Iffley. In 1861 he was appointed Vicar of Streatley, Berks, and in 1880 Rector of Whitechurch, Oxon., where he remained until the time of his death, 1899 April 7. He had a private observatory at Rose Hill, Iffley, where he worked a good deal. He was obliged to give this up when he went to Streatley, but he still kept up much interest in astronomy. He was elected a Fellow of the Society 1847 November 12, and communicated two short notes to the *Monthly Notices*, one (in *Monthly Notices*, vol. xxxii. p. 317) relating to the observations of the Aurora of 1872 February 4 and containing some interesting remarks as to the height of the Aurora as deduced from observations of an auroral arch made at Streatley simultaneously with observations at Greenwich, 1870 October 24. Mr. Slatter deduced a height of 118 miles above the Earth's surface, on the assumption that the same phenomenon was observed at both places. He mentions one other case, in which the identity of the phenomenon observed was satisfactorily established, and in this case with a base of nineteen miles a height of less than three miles was deduced.

He married Elizabeth, daughter of Richard Wootten, Esq., of Iffley, and had one daughter.

HALE WORTHAM was born at Royston, 1822 July, and was the son of the late Thomas Wortham, solicitor, of Royston. He was educated at Mr. Carver's school at Melbourn, Cambs, and King's College, London. In 1844 he was admitted to practice, and on the death of his father, which occurred shortly afterwards, he succeeded to his business, living alone at Royston. In 1871 December he was appointed Clerk of the Peace for the County of Cambridge, in place of Mr. H. R. Evans, of Ely. When the Local Government Act came into operation in 1888, and many of the functions discharged by Quarter Sessions were transferred to another authority, an enormous amount of work devolved upon Mr. Wortham. He was appointed Clerk to the newly constituted

County Council, and occupied that post until his death. He was also Clerk to the Magistrates of the Arrington and Melbourn Division, and of the Odsey (Hertford) Division; and was a Deputy-Lieutenant for Cambridgeshire. Mr. Wortham owned considerable property in Royston, where he had lived all his life. He died, after a short illness, 1899 April 18.

He was elected a Fellow of this Society 1856 March 14.

PROCEEDINGS OF OBSERVATORIES.

THE following reports of the proceedings of observatories during the past year have been received from the Directors of the several observatories, who are alone responsible for the same :—

Royal Observatory, Greenwich.

With the transit circle 12,104 observations of transits and 11,088 of zenith distances were made in 1899, about 3000 of these observations having been made below pole.

The total number of stars observed is about 5000, about 1400 of these being within 10° of the pole.

The Sun was observed 204 times with the transit circle, its horizontal diameter 162 times, and its vertical diameter 179 times.

The Moon was observed 130 times ; the mean errors in R.A. of Hansen's Lunar Tables with Newcomb's corrections is $-0^s.101$. The errors since 1883, when Newcomb's corrections to Hansen's tables were introduced into the *Nautical Almanac*, are as follows :—

	^s		^s		^s
1883	+0.031	1889	+0.010	1895	-0.066
1884	+0.018	1890	+0.020	1896	-0.088
1885	+0.024	1891	+0.079	1897	-0.154
1886	+0.029	1892	+0.083	1898	-0.160
1887	+0.059	1893	+0.034	1899	-0.101
1888	+0.090	1894	-0.016		

The R—D discordance, which had become very small in 1897 and 1898, shows an increase in 1899, the correction to direct observations found for last year being $+0''.08 + 0''.22 \sin Z.D.$ The special observations of pairs of stars directly and by reflection, which have been made for the four years 1895, 1896, 1897, and 1898, show a satisfactory agreement with the ordinary observations reflection and direct at the same transit, confirming the striking diminution in the value of the R—D discordance in 1897 and 1898 as compared with 1895 and 1896. It results, therefore, that the R—D discordance is not in any way due to the circumstance that the direct observation is taken immediately after the reflection observation.

The Second Ten-Year Catalogue of 6892 stars for 1890, from observations made in the years 1887-1896, is in the press, the first fifteen hours being already printed. The catalogue consists largely of fundamental stars and of stars from Groombridge's Catalogue of 4243 circumpolar stars, epoch 1810, of which about 3600 have been observed. About 2000 stars in the catalogue have been observed above and below pole, so that the catalogue contains considerable material for discussion of latitude and refraction.

Comparisons have been made between this catalogue and the fundamental catalogues of Professor Newcomb and Dr. Auwers, the Greenwich Ten-Year Catalogue for 1880, the Cape Catalogue for 1890, the Zone Catalogues of the *Astronomische Gesellschaft*, the Radcliffe Catalogue (1845), and Groombridge's Catalogue (1810).

The re-observation of the stars of Groombridge's Catalogue, which was the principal object of the Second Ten-Year Catalogue, furnishes material for determination of the proper motions of more than 4000 stars from observations about eighty years apart, with intermediate positions in the Radcliffe Catalogue of 1845. For use in the Second Ten-Year Catalogue, provisional proper motions have been determined for 163 stars, for which the proper motion in R.A. or N.P.D. amounted to $0''.1$ in arc of a great circle, and had not previously been determined. It is proposed now to undertake the determination of the proper motions of all the Groombridge stars; but before doing this it is advisable that Groombridge's observations should be re-examined in view of the large systematic errors in R.A., apparently due to faulty determination of azimuth error.

The Altazimuth.—This instrument has required a good deal of attention during the year. In January several of the screws attaching the telescope to the axis were found to be loose, and bolts were substituted. At the same time the attachment of the eye-end to the tube was strengthened and the object glass was re-centred.

On June 21, and again on October 31, one of the pivots fired and had to be re-ground. On the latter occasion new Y's made of bell-metal were substituted for cast iron. On September 3 the object glass was found to be loose, and was fixed firmly.

During the year 1719 transits and 1492 zenith distances were observed in the meridian. The Moon was observed 21 times in right ascension and 24 times in zenith distance on the meridian, and 9 times in other azimuths. The errors of the microscope screws have been determined, and found to be small, and in order to eliminate as far as possible the effect of wear in the future, the screws have been reversed and the heads re-figured in the opposite direction for one of each pair of opposite microscopes.

In November a double pair of webs, about $4\frac{1}{2}'$ apart, were inserted in each microscope, so that two divisions of the circle

may be read to give the correction for runs, and eliminate any "drunkenness" of the screw.

A re-determination of the division errors of each degree of the fixed and movable circle by a symmetrical process was begun in December, and has just been completed.

28-inch Refractor.—Measures of distance and position-angle have been made of 556 double stars, each star being observed on the average on 2.3 nights. Of these, 134 are less than 0''.5 apart, 131 between 0''.5 and 1''.0, 92 between 1''.0 and 1''.5, 40 between 1''.5 and 2''.0, and 159 over 2''.

Among the stars the following interesting pairs, which were measured several times, may be mentioned :—

	Mags.	Dist.	No. of Nights.		Mags.	Dist.	No. of Nights.
Aldebaran	1, 14	31''	3	Σ 2525	7½, 7½	0.3	9
β 883	7½, 7½	0.3	8	γ ² Androm.	5, 6	0.3	9
ζ Herculis	3, 6	0.5	12	ε Hydr. A.B.	3½, 7½	0.2	4
70 Ophiuchi	4, 6	1.6	11	Σ 1639	6½, 8	0.2	4
κ Pegasi	4, 5	0.3	11	0Σ 225 A.B.	8, 11	0.7	4
β 151	4½, 6	0.6	9	99 Herc.	6, 11	0.9	3

Thirty-six occultations of stars by the Moon have been observed during the year by one or more observers, 28 of them occurring during the lunar eclipse of December 16.

Thompson Equatorial.—A number of improvements in detail have been made in the instrument during the year. The driving of the telescope has been much improved by the attachment of a weight to the sector, which keeps it constantly bearing on one side, and by the substitution of an astronomical clock with zinc and steel pendulum for a wood rod pendulum for the electric control. The Hodgson 6-inch refractor, the guiding telescope of the 30-inch reflector, has been fitted with scales at right angles and mounted more firmly. An occulting shutter has been arranged for use with the 26-inch refractor in the photography of bright stars with faint companions.

With the refractor 224 photographs have been taken. These include 34 of *Neptune* and its satellite, of which 16 photographs taken on 15 nights have been measured; 21 of Comet *a* 1899 (Swift), of which 15 taken on 14 nights have been measured; 120 of 44 double stars, of which 58 of 25 stars have been measured; and 9 for parallax.

With the reflector 79 photographs have been taken. These include 41 of *Eros*, of which 32 taken on 24 nights have been measured, one of Comet *b* 1899 (Tuttle), and photographs of the *Pleiades* and of the *Orion* nebula at the principal focus.

Experimental photographs have been taken with the spectro-scope of the Solar Spectrum, and of *α Lyrae* and *α Cygni*. Some additions have been made to the spectroscope in detail, of which

the most important are the arrangements for guiding on the slit according to the method of Sir W. Huggins.

With the astrographic equatorial 539 plates with 1025 exposures have been taken on 125 nights. Of these, 149 have been rejected—viz. 17 because the exposure was interrupted by cloud, 23 because the photographs did not come up to the standard in showing faint stars, 28 owing to bad guiding or wrong setting, 20 owing to imperfect printing of the reticule, 36 owing to defects in the photographic plates, and 25 from miscellaneous defects. The number of rejections is unusually large; 15 of the imperfectly printed reticules occurred in August through a temporary difficulty with the electric light; 35 of the defective plates occurred in a batch near the end of October. Of the 390 successful plates, 201 are for the chart, 171 for the catalogue, 7 are photographs of standard areas, and 11 are for the adjustment of the equatorial.

The following table shows the progress of the photo-mapping of the heavens to the end of 1899 :—

		Catalogue.	Chart.
Number of successful fields on 1898 Dec. 31	...	971	923
" " " " taken in 1899	...	171	201
Number previously passed rejected in 1899	...	92	62
Number of successful fields, 1899 Dec. 31	...	1050	1062
Number still required	...	99	87

Positives on glass of 96 chart plates were made during the year, which, with the 898 reported last year, and striking off 4 rejected since, gives a total in hand of 990.

During the year 1899, 135 plates were measured in the direct and reversed positions; at the date of this report the measurement is completed from 64° to 72° N. decl., with the exception of two plates.

Copy for press of the measures is prepared for zones 68° and 69° , and that for zone 70° is in progress. The measures are printed for zone 64° , and the first sheet of zone 65° is in the printer's hands.

The plate constants and the residuals of the reference stars, derived from the catalogues of the *Astronomische Gesellschaft*, are computed for the plates whose centres are at declinations 65° to 69° inclusive. The catalogue of the Dorpat zone (70° to 75° N. decl.) of the *Astronomische Gesellschaft Catalogue*, which will be required for the plates whose centres are at declinations 70° to 75° , is not yet published; but the director, Dr. Lewitzki, has kindly promised to forward a provisional catalogue in manuscript.

The total number of stars measured in the different zones compared with the number in the *B.D.* and the *A.G.C.* are approximately :—

Zone.	No. of Stars measured on the Plates.	No. in B.D.	No. in A.G.C.
64°	8954	1900	1200 (Helsingfors)
65°	9237	2001	844 (Christiania)
66°	9494	1684	745 "
67°	9600	1285	574 "
68°	10,200	1429	685 "
69°	10,650	1389	646 "
70°	11,400	1345	
71°	11,000	1251	
Totals: Decl. 64° to 72°	80,535	12,284	

For the chart plates with forty minutes' exposure arrangements have been made to count the number of stars shown on the areas corresponding to those measured on the catalogue plates. The instrument originally made for measuring the Transit of *Venus* photographs and subsequently modified for astrophotographic plates has been adapted for counting simultaneously the corresponding star images shown on the overlapping portions of two plates, a hand billiard-marker being used, as suggested by Professor Turner, to facilitate the counting. The number of stars on chart plates has now been counted for rather more than half of the zone 65° to 66° N. declination. We shall thus have available for comparison the number of stars on corresponding areas, shown with exposures of 20^s, 3^m, 6^m, and 40^m on photographic plates and contained in the *Astronomische Gesellschaft* Catalogues and *Bonn Durchmusterung* respectively. The duplex form of measuring instrument specially lends itself to this work, as the stars in any defined area of the sky can readily be counted without overlap, and the simultaneous examination of the images on the two overlapping plates eliminates false stars.

Photographs of the Sun were obtained on 208 days with the Thompson photoheliograph of 9-inch aperture, which is now mounted on the Thompson photographic refractor of 26-inch aperture. Of these, 430 have been selected for preservation, including 14 with a double image of the Sun, taken to determine the position of the wires with reference to the parallel of declination. Photographs have also been received from India up to 1899 September 29, and from Mauritius up to 1899 August 6, leaving only two days for which no photograph is available for measurement in the year ending with the date of the last Indian photograph received.

The Greenwich photographs have been measured in duplicate up to the end of 1899, and the Indian and Mauritius photographs so far as they have been received. The areas and heliographic positions of the spots and faculae have been computed throughout, and the complete results for 1898 have been printed, and the copy for press for 1899 is ready so far as June 23. The decline

in the solar activity has been very marked during 1899, the number of days without spots having risen from 8 in 1896, 32 in 1897, and 48 in 1898 to 85 in the first nine months of 1899, whilst the mean daily spotted area for 1899 is estimated from the materials at present to hand as only 100 millionths of the Sun's visible hemisphere, as compared with 375 in 1898.

The reduction of the observations made for the longitude of Killorglin, in the West of Ireland, mentioned in last year's report, was completed at the end of May. The publication of the results of the various determinations of longitudes made in the years 1888 to 1898 has now been taken in hand—viz. Paris in 1888, Dunkerque in 1889, Paris in 1892, Montreal, Canso, Waterville in 1892, Killorglin in 1898, and observations at Greenwich at contiguous stations to test the instruments in 1893 to 1897. The copy for press for the 1888 and 1892 Paris longitudes is prepared and will be sent to the printers without delay.

At the desire of the International Geodetic Association arrangements have been made with the Bureau des Longitudes and the Paris Observatory for a re-determination of the longitude of Paris, in view of the discordance between the results found by the French and English observers respectively in 1888 and again in 1892. It is proposed to undertake this re-determination after the publication of the observations made in the previous determinations has afforded an opportunity for full discussion of the results found in 1888 and 1892.

The printing of the annual volume of *Greenwich Observations* for 1897 was completed in November. The Transits, Zenith Distances, Star Ledgers and the Annual Catalogue as far as 15^h, and the whole of the Solar results have been printed for 1898.

The new Observatory building was finally completed last March. Three wings of the ground floor have been fitted with adjustable book-stacks, and the Library has been transferred to them. The books are being rearranged, and it is proposed to make a new card catalogue. The wings of the upper floor have also been fitted up with similar book-stacks for the storage of manuscripts and records and of the stock of Greenwich publications.

Royal Observatory, Cape of Good Hope.

The physical laboratory and the new record room were completed and available for use in July. The latter provides suitable accommodation for the measurement and preservation of astrographic photographs, and both buildings have proved admirably adapted for their purposes.

The contract-dates for delivery of the new transit circle and its observatory have been greatly exceeded, and neither instrument nor observatory has yet been received from the makers.

A chronograph room has been erected near the site of the new transit circle, but the chronograph itself has not been received from Messrs. T. Cooke & Sons.

The 24-inch photographic object glass of the McClean equatorial was returned on October 31, at the request of Sir Howard Grubb, for rectification of faults in the marginal images and in the general chromatic correction.

Part 2, volume ii., of the *Annals of the Cape Observatory*, containing a catalogue of Southern double stars, has been passed through press.

Volume v. of the *Cape Annals*, being the third and last part of the *Cape Photographic Durchmusterung*, has been passed through the press; the work will therefore be very soon ready for distribution.

A summary of the results of the revision of the *C.P.D.*, so far as it has been completed, is contained in the Introduction, but the complete revision, with details of observation of variable stars, investigations of proper motion, complete lists of errata of catalogues compared with the *C.P.D.*, &c., will be published in a subsequent volume of the *Annals*.

A part of volume viii. of the *Cape Annals*, containing "Helio-meter Investigations on the Parallaxes of the Principal Fixed Stars of the Southern Hemisphere" is in the press. The remainder of the volume will contain the results of "Helio-meter Observations of the Satellites of Jupiter."

The Cape General Catalogue of 3007 stars for 1890, with appendices, has been distributed.

The day-numbers for the year 1901, corresponding to Finlay's star-reduction tables, have been distributed; those for 1902 are printed and will be soon distributed.

The annual results of meridian observations 1896-97 are in the press. The MS. of these results for 1898 is ready for press. The annual results of the meridian observations 1866-70, made under the direction of Sir Thomas Maclear and recently reduced, are in the press. The annual results of meridian observations 1877, made under the direction of Mr. Stone, are also in the press; those for 1878 and 1879 are ready for press.

The Cape General Catalogue of 1905 stars for the equinox 1865, based on the Cape meridian observations 1860 to 1870, has been completed and passed through the press, and should soon be in the hands of astronomers. This work completes the arrears of publication of the Cape meridian observations.

The list of 2798 zodiacal stars for the equinox 1900, prepared by H.M. Astronomer in accordance with Resolution 9 of the "International Conference on Fundamental Stars," held at Paris in the year 1896, has been passed through press and distributed.

The work of the present transit circle has been chiefly confined to the completion of the observations of standard stars required for the reduction of the international "Catalogue

Plates." During the year the whole of the standard stars between Declination -48° and -51° (both inclusive) have been observed, with a minimum of three observations for each star. We have thus now good recent meridian places of from 10 to 12 well-distributed standard stars for each of the plates of the Cape astrographic zone -40° to -52° .

The observations made with the transit circle during the year have been :—

Meridian Transits	...	...	9450
Determinations of Z.D.	...	...	8947
" Collimation	...	...	99
" Level	...	...	331
" Azimuth	...	...	306
" Runs	...	...	317
" Nadir	...	...	318
" Flexure	...	...	21

The reductions of the meridian observations to mean place both in R.A. and N.P.D., and the formation of the Ledgers, is complete to 1899 December 31.

The General Catalogue of standard stars Declination -40° to -52° for the Cape astrographic plates, now in course of preparation from the Cape meridian observations 1896-99, will contain 8556 stars.

A new working list for the transit circle has been prepared, and contains :—

1. All stars of $8\frac{1}{2}$ magnitude or brighter which are catalogued in the *C.P.D.*, but which are not to be found in any catalogue of precision yet published.
2. All of the 2798 stars of the zodiacal list.
3. All stars of which occultations have been observed at the Cape, and which do not occur in the Cape General Catalogues for 1885 or 1890.
4. Stars which, from the revision of the *C.P.D.*, appear to require further meridian observations to settle questions connected with their proper motion.
5. Stars used for latitude determination in either of the two Cape geodetic surveys.
6. Comet comparison stars.

The new transit circle will be entirely devoted to systematic meridian observation of the Sun, *Mercury*, *Venus*, and fundamental stars.

Observations of 115 separate phenomena of occultations were obtained as follows :—

	D.B.	D.D.	R.B.	R.D.	Total.
Predicted by the N.A. Office ...	2	13	2	15	32
Other occultations	0	73	0	10	83
Total number of separate phenomena	...	...	...	...	115

Of these phenomena, twenty-one were observed by two observers, and six by three observers.

A list of 893 occultations observed at the Cape between 1881 and 1898 has, at the request of Monsieur C. André, been published in the *Astronomische Nachrichten*, Nos. 3599-60.

Tuttle's Comet was observed on seven nights, and Swift's Comet on one night, with the 7-inch equatorial; Tempel's Comet was observed at meridian passage on twenty nights with the transit circle. Finlay's Comet was searched for on four nights with the 18-inch telescope of the McClean equatorial, but without success. The results of these observations of comets have been communicated to the *Astronomische Nachrichten*. In addition to the lists of stars mentioned in last report in connection with the revision of the *Cape Photographic Durchmusterung*, two further lists, consisting of stars contained in catalogues of precision but missing in the plates, have been received from Professor Kapteyn. All stars in these and previous lists have now been looked for, and a summary of the results appears in the introduction to the third part of the *C.P.D.* A further list of suspected variable stars is also under observation, together with a few other stars chosen chiefly from Chandler's third catalogue. Some of the results have been published in the *Astronomical Journal*, Nos. 468 and 470. The star *C.P.D.* $-41^{\circ}.1681$ has been found to be an Algol variable, and the star *C.P.D.* $-49^{\circ}.10361$ a variable with the remarkably short period of $7^{\text{h}} 28^{\text{m}}$.

In course of these revisions eighteen previously unrecorded double stars have been found by Mr. Innes with the 7-inch equatorial, two by Mr. Cox with the transit circle, and one by Mr. Pead with the same instrument.

Twenty-one close double stars, previously unmeasured, have been measured with the Repsold micrometer attached to the 18-inch visual telescope of the McClean equatorial, and two new close double stars have been found by Mr. Innes with the same instrument. Many previously unrecorded faint *comites* to known double stars have been noted, but are not included in these figures.

The McClean Equatorial has been chiefly employed in connection with the slit spectroscope, as the colour-correction of the object-glass was unfavourable for use with the object-glass prism.

A great deal of time has been given to investigations on the systematic errors to which measures of velocity in the line of sight are liable.

Between January 19, when the slit spectroscope was mounted,

and October 13, when the photographic object glass was dismounted, the following photographs were secured :—

	Plates.
With the object-glass prism	15
Stellar spectra with slit spectroscope	114
Chemical spectra	106
Investigation of the colour-curves for focus of the slit spectroscope and for adjustment of collimator for rays of different colours (Newall's method) ...	111
Total ...	346

A number of these spectra have been measured, and papers have been communicated to the Royal Society on the existence of oxygen and silicon in certain classes of star spectra.

Regular observation of all oppositions of major planets with the heliometer has been continued; the following observations were secured in 1899 :—

	No. of Measures.
Opposition of <i>Mars</i>	18
„ <i>Uranus</i>	49
„ <i>Jupiter</i>	40
„ <i>Neptune</i>	33
„ <i>Saturn</i>	10

In Triangulation I. (which connects thirty-six stars available for *Uranus* in 1898, 1899, and 1900, *Saturn* in 1898, and *Jupiter* in 1900), forty-nine distances in the triangulation with twelve measures of the standards have been obtained in 1889, in addition to 141 distances and seventy position angles measured in 1897 and 1898. In Triangulation II. (connecting together nineteen stars required for heliometer observations of *Neptune* in 1897, 1898, 1899, and 1900), there have been measured in 1899 thirty distances in the triangulation and thirteen standards, in addition to eighty-three distances with thirty standards and seven position angles with four standards measured in 1898.

In the triangulation of the *Jupiter* comparison stars for 1898, thirty-six distances with seventeen measures of standards have been observed; in the triangulation of the *Jupiter* comparison stars for 1899, fifty-five distances with nineteen standards and twelve position angles with six standards were observed. All the observations connected with the triangulation of *Jupiter* standard stars were made in 1899.

The heliometer triangulation of the South Polar area has been continued. During the course of the year 202 observations of distance in the triangulation, with sixty-five observations of the standard distance, have been secured, in addition to 311 observations of distances and 103 observations of the standard distance secured in previous years. The heliometer observations for this

triangulation are now nearly complete. In connection with the same object, nine astrographic plates, covering the same area, have been secured. The combination of the heliometer and photographic measures with all existing data from meridian observations will be employed to derive definitive places of the stars within 2° of the South Pole for the equinox 1900.

Forty sets of heliometer observations for stellar parallax, and $14\frac{1}{2}$ sets of observations of red stars relative to normally coloured comparison stars at large hour angles E. and W. of the meridian, have been observed.

Heliometer observations of the conjunction of *Mars* with *Regulus* were made on two nights.

As stars used to determine the screw value of the Repsold micrometer when attached to the McClean equatorial, the distance and position angle of ζ_1 and ζ_2 *Reticuli* were observed with the heliometer on three nights, and of β and γ *Horologii* on two nights.

Comet Swift was observed with the heliometer on eight nights, its position being referred to twenty-seven different stars.

Nearly all the heliometer observations have been reduced to arc, corrected for aberration, refraction, &c., and are ready for final discussion.

Mr. de Sitter has completed the series of observations with Zöllner's photometer which he carried out for the purpose of determining the relation between the visual and photographic magnitudes of stars in different galactic latitudes.

The systematic reduction of the series of 550 heliometer observations of the mutual distances and position angles of *Jupiter's* satellites, and the comparison of the observed with the corresponding tabular quantities, is now completed. The coefficients of such elements of the system and such periodic terms as can be determined from the observations have been computed, and the normal equations are formed. The solution of the normals is not yet completed, but it is already evident that the results will furnish considerable and accurately determined corrections, especially to the nodes and inclinations of the orbits of the satellites.

With the astrographic telescope the following work has been accomplished :—

	No. of Plates.	No. of Exposures.	Duration of Exposure.
Triple image Chart Plates, passed	152	456	30^m
" " " " rejected	40	120	30^m
Revision Catalogue Plates ...	184	552	$6^m, 3^m, 20^s$
Iris Plates... ..	78	468	3^m to 1^m
Galactic Comparison Plates ...	6	12	10^m
Polar Plates	9	27	$6^m, 3^m, 20^s$
Various (foci, adjustments, &c.)...	12		
	481		

With reference to the revision catalogue plates, it is intended, as mentioned in last report, to repeat the whole series, in order to bring the epoch at which the plates were taken nearer to that at which the comparison stars were observed on the meridian.

The 78 plates of *Iris* were taken during the period July 11 to the end of the year, and the series will be continued until the middle of January 1900. There are 6 exposures on each plate. It is intended to utilise the results of measurement of these plates, in combination with meridian observations of a number of comparison stars, to determine the mass of the Moon.

The new measuring machine, devised by H.M. Astronomer, which is mentioned in last report, has been in constant use throughout the year, although a great deal of time has been lost in training observers. The second measuring machine of the same type was received from Messrs. Repsold only in the beginning of November; but its micrometer had to be returned for some small alterations, so that only one machine has been available throughout the year for all purposes.

During the year 103 plates containing 38,758 stars have been measured in both coordinates in each of two reversed positions of the plate, and all the standard stars on each plate have been similarly measured by both the observers. When a coordinate of any star, as measured in one position of the plate, differs by $0''.6$ from the corresponding coordinate resulting from the measure in the reversed position of the plate, the observations in both positions have been repeated. The total number of plates now definitely measured is 126. The conversion of the measures into rectangular coordinates has been completed for 102 plates, and for 87 of these the work is completely examined and the final copy prepared for press.

With cameras attached to three equatorials, attempts were made to photograph the paths of the *Leonid* meteors on November 14, 15, and 16. Plates were exposed from the time of rising of the radiant until dawn, but without success.

The numbers of meteors observed by eye were:—

Nov.	Separate Leonids.	Hourly No.
14	15	12.0
15	6	3.8
16	4	2.3

The seismograph was brought into use on August 1, and the records have been forwarded monthly to Professor Milne since that date.

The geodetic survey of Rhodesia has been steadily pushed forward. H.M. Astronomer visited Rhodesia in May, reorganised the observing party, and started the arc of meridian from Gwelo northwards approximately along the 30th meridian of E. longitude. From January to May 15 ten stations were occupied, extending eastward to Bungwe (lat. $19^{\circ} 51'$ S., long. $30^{\circ} 19'$ E.). Between

May 15 and July 20 fourteen stations were occupied with the theodolite, and the angles of the triangles in the arc were measured as far as lat. $18^{\circ} 35'$ S. The reconnaissance and beaconing of fourteen stations carried the arc to N'yamanje (lat. $16^{\circ} 30'$ S., long. $30^{\circ} 45'$). Here the smoke from grass fires compelled stoppage of the work for the season, and the party returned, *via* Salisbury, to Gwelo, where latitude and azimuth were determined. The intended telegraphic determination of the longitude of Gwelo was prevented by the outbreak of the Transvaal war, and interruption of telegraphic communication by the Boers. The astronomical point at Gwelo was connected with the main triangulation, and the observing party was disbanded for the season. During the year astronomical latitude was determined at five stations, and astronomical azimuth at two stations. Complete reorganisation will be required for northern extension of the work, and transport by native carriers must be substituted for the wagon transport hitherto employed. Mr. Alexr. Simms, who has been in charge of the field work throughout, returned to the Observatory in the end of December *via* Beira and Delagoa Bay, where he will be occupied in connection with the reduction of the observations, and in preparation for renewal of field work in March, when the season is again suitable. The operations of the Anglo-German Boundary Survey are in steady progress, but have been rendered very tedious and indirect by the flat and arid character of the country.

The report of the survey of a part of the Cape Colony and British Kaffraria made by Captain Bailey, R.E., in 1859-62, was printed and presented to the Cape Parliament in 1863. The work contains many errors and inconsistencies, and, in its present state, is quite unfit to form a basis for further accurate survey. Accordingly, all available original data have been collected, and the whole work has been recomputed and reduced to consistency with the results of the geodetic survey. The new work is in the press. The meteorological observations made during 1899 have been communicated to the Cape Meteorological Commission.

No change has occurred in the staff except that Mr. W. de Sitter, a former pupil of Professor J. C. Kapteyn, who has served as a computer at the Cape Observatory since August 1897, returned in December to Holland to take up the post of assistant at the Astronomical Laboratory, Groningen. At the Cape Mr. de Sitter availed himself of the opportunity to study practical astronomy, and has carried out several researches of considerable importance during his stay.

Two computers, and also the optical fitter and the carpenter, who were all members of the Cape Volunteer Artillery, have been called out for active service at the seat of war; the work of the Observatory has necessarily suffered by their absence.

Royal Observatory, Edinburgh.

The Observatory buildings and grounds have been maintained in excellent order by H.M. Office of Works. The instrumental equipment has been increased by the acquisition of a Cooke triple object-glass of 6-inch aperture. This has been mounted on the equatorial stand in the "6-inch" house. Its performance for observation of double stars when the magnitudes are very unequal, and for occultations, has been found extremely satisfactory, the achromatism and correction for figure being practically perfect.

A vacancy was caused in the personal staff of the Observatory by the lamented death of Mr. Andrew James Ramsay on March 5. Born at Crieff 1862 March 27, he had thus not quite completed the 37th year of his age. His loss is keenly felt by his colleagues, with whom he had been associated for a number of years, both during his University career and more particularly since his appointment as Assistant Astronomer in 1893. A short account of his astronomical work will be found in vol. ix., No. 6, of the *Journal of the British Astronomical Association*. The vacancy was filled in April by the appointment of Mr. George Clark, M.A., to the position of Second Assistant Astronomer.

The time service for the cities of Edinburgh and Dundee has been carried on as in past years. In addition to the clocks used for automatically firing the gun and dropping the time-ball, four other clocks are directly controlled by the Molyneux Mean Time Clock of this Observatory, besides a number of others controlled by secondary circuits. The signal by time-ball was unfortunately interrupted from September 30 to October 10, for repair of part of the machinery, and again on November 3, when it was considered inadvisable to raise the ball on account of the violence of the wind. The gun was accidentally fired incorrectly on April 4, through a derangement of the clock at the gun, and was under repair on May 25. With these exceptions, the time service has been satisfactorily carried out. Time observations were made on over a hundred nights with the meridian circle, and from these the rate of the Brisbane sidereal clock was determined. This clock, which is enclosed within an airtight case, continues to give satisfaction, its rate having altered but slightly during the year. In September the pendulum of the Frodsham sidereal clock was suspended from a new cast-iron back, to which the contact-springs of the chronograph circuit are also attached. Formerly the springs were fixed to the wooden back of the clock-case, and the unequal expansion of the wood and the steel pendulum-rod prejudicially affected the clock rate, as well as the working of the chronograph. The improvement thus effected in the going of the clock and the action of the contact-springs at once became apparent.

The meridian observations have been carried out during the year by Dr. Halm, assisted since July by Mr. Clark. The programme of observations has been the same as that of last year, comprising the list of *Nautical Almanac* zodiacal stars and the stars employed by Dr. Gill in his heliometric measurements of the positions of the outer planets. In addition to these, regular observations of the Pole Star in both coordinates and of the standard stars used for determining the correction of the clock were made on all possible occasions. The total number of observations made is 2000, for all of which the chronograph signals have been duly recorded and the means of the microscopes deduced. The instrumental errors were ascertained at frequent intervals, and were found to remain remarkably constant; the difference, for example, between the maximum and minimum values of the azimuth amounting to no more than $2''$.

As regards the new reduction of the observations made under the direction of the late Professor Henderson, the right ascensions from 1834 to 1845 are now finished, the only part of the work still to be done being the reduction of the mean places to the equinox 1840.0. Considerable progress has also been made in the reduction of the declinations, the years 1841 to 1845 having been completed, while comparatively little now remains to be done to the preceding years. It is therefore confidently expected that the final results will be published in the course of the present year. The application of the clock corrections, and those for the position of the instrument in right ascension were carried out for the most part by Mr. Clark, while Dr. Halm chiefly devoted himself to the reduction of the declinations. This latter part of the work was greatly facilitated by the admirable investigation, of Professor Boss, into the division errors of the mural circle employed by Henderson. In the course of the computations much assistance was rendered by Mr. Neustadt, who has acted as temporary computer.

Some damage was caused to the East Dome by a violent storm on the night of November 10, a part of the outer copper covering of the roof being torn away. The repairs were executed by H.M. Office of Works before the end of the month, the torn copper, which weighed 16 oz. to the square foot, being replaced by stronger material weighing 22 oz. to the square foot.

The 15-inch refractor was used during the year by Mr. Heath for micrometric observations of the minor planets. A few occultations were also observed, and in June eight determinations of the place of Swift's Comet were obtained by Mr. Heath and Dr. Halm. A number of observations of close binary stars were also made by Dr. Copeland.

The occultations of small stars predicted to take place during the nearly total Lunar Eclipse of December 16 were observed with three telescopes. In all, thirty-three observations of stars were secured, thirteen by Dr. Halm with the 6-inch, nine by Mr. Heath with the 15-inch, and eleven by Mr. Clark with the

12-inch reflector. *Neptune* was occulted soon after the eclipse, but nothing was seen of it by any of the observers here.

The meteorological observations have been made by the staff on the same lines as in former years. The bi-daily readings of the barometer, wet and dry bulb thermometers, wind and cloud, and daily readings of the shaded and exposed maximum and minimum thermometers, have been continuous throughout the year. The Robinson Anemometer and King's Barograph have also been in operation without interruption. A monthly copy of the daily readings has, as usual, been supplied to the Secretary of the Scottish Meteorological Society for the use of the Registrar-General for Scotland, and the monthly means have been published in the Registrar's quarterly returns. The weekly readings of the Rock thermometers at Calton Hill have been continued. The observations since 1879 are now being prepared for publication by Mr. Heath, along with a summary of the whole series from the commencement in 1837 to the end of 1899.

The two bifilar pendulums and photographic recording apparatus have been kept in action all the year. Though the record is fairly continuous, no disturbance of an interesting character has been found on the photographs. During the summer considerable difficulty was experienced from the stopping of the clock and the gradual discoloration of the paraffin oil in which the pendulum mirrors are suspended. Eventually, rectified spirit of turpentine was substituted for the paraffin oil. So far, this has proved more transparent to photographic rays than the paraffin oil, with a corresponding improvement in the distinctness of the curves.

Watch was kept for the expected shower of *Leonid* meteors on the nights of November 14 and 15. The night of the 14th was cloudless ; but on the 15th the sky was partly obscured by haze, and at 14^h a thick fog came on. On both nights the presence of a nearly full Moon made observations of the fainter meteors difficult or impossible. The paths of 74 *Leonids* were laid down on previously prepared maps by Dr. Halm and Mr. Clark. From these two determinations of the radiant-point were computed, by Mr. Clark, and the result laid before the Society in a paper which appeared in vol. lx., No. 2, of the *Monthly Notices*. An attempt was made by Mr. Heath to photograph the radiant-point with two cameras, one of which carries plates, 18 × 16 inches, attached to the tube of the 24-inch reflector, but without success. A few *Bielids* were unexpectedly seen on the evening of Saturday, November 25.

Armagh Observatory.

On January 31 a micrometer for measuring photographic plates was received from Messrs. Troughton & Simms, paid for by a grant made by the Government Grant Committee. It is a modification of the Greenwich instrument figured in *Monthly Notices*, vol. liii. p. 327, and can be used either for measuring rectangular

coordinates, one at a time, or polar coordinates. The settings on the objects are made with a microscope with a simple cross-wire, while the glass scale is read by a micrometer carrying parallel wires. The plate holder is furnished with a position circle, and is counterbalanced by a weight attached to it by a chain passing over a pulley, the whole instrument being inclined at 45° to the horizontal plane.

Owing to the delay caused by various minor alterations which had to be made in the instrument, as well as by other circumstances, regular work with the instrument has only recently been commenced. Several plates of the *Pleiades*, lent by Dr. Roberts, have been measured for the determination of scale value, distortion, &c., and a number of plates of nebulae are shortly expected, which Dr. Roberts has kindly undertaken to furnish for the purpose of their being measured and discussed at Armagh.

During the nights when the *Leonids* were expected it was totally cloudy here, except from 1.30 to 2.0 on the morning of the 16th, when three observers only saw two meteors, one of which was not a *Leonid*.

Cambridge Observatory.

Meridian Circle.—The meridian circle was used for observation on 122 nights in the course of the year 1899, and frequent observations were taken by day of standard stars, especially *Polaris*.

The re-observation of the faint stars, of which the places in the catalogue of the *Astronomische Gesellschaft* depend each on a single observation, which was begun in 1897 March, is now completed. To this end 805 complete observations of these stars were made during the year. The reduction of these observations is approaching completion, and in a short time the results will be ready for examination and comparison with the single places given in the Catalogue.

In 1899 March the work of observing Dr. Gill's list of heliometer comparison stars was begun. Six hundred and eighty-four observations of 92 stars have been made, and the places are obtained and reduced to the mean equinox at the beginning of the year.

The list of Harrow occultation stars, furnished by Col. Tupman, is approaching completion, 331 observations having been made during the year; so that at present there remain only 16 of these stars unobserved. The reductions of all these observations are well-nigh complete.

An observing catalogue of stars near the ecliptic is in course of preparation, and the work of observation and reduction is actually begun. Three hundred and thirty-two observations of these stars have already been made in the latter part of the year.

As an essential part of the work there have also been made 762 observations of standard stars for clock error, and 87

observations of *Polaris* at the upper transit, and 103 at the lower, for instrumental deviation. The observations of *Polaris* have also been used in making a fresh determination of the intervals of the wires, although these have remained intact during the year.

The nadir point, level, and line of collimation have been carefully and regularly observed, and the constants for instrumental correction have been obtained from 160 equations.

After each observation for level and line of collimation the transit wires have been always adjusted so as to leave the observations practically free from error of collimation, and from the effect of diurnal aberration.

Sheepshanks Photographic Equatorial.—The work for the year has consisted almost entirely of experiment and alteration. In 1899 February the flexure of the objective tube was determined. It was found to be large and unsymmetrical with respect to the meridian, and Sir Howard Grubb undertook to make a new and much stronger tube. Trial photographs showed very poor definition, due to air currents in the tube. The instrument had been sent to Cambridge without any provision being made to close in the elbow joint and protect the mirror. March was spent in designing and making an experimental covering for the elbow joint, both above and below, by which the free circulation of air in the path of the rays was almost entirely prevented. So much improvement in the definition resulted that it was decided to carry out the plan in permanent form. The necessary additions to the instrument, in accordance with specifications and plans prepared at the Observatory, were ordered from Sir Howard Grubb. In June the old objective tube was returned to him, and the work put in hand. It was completed and the instrument partly readjusted by Christmas. In 1900 January the plane mirror was resilvered at the Observatory, and the instrument is now, at the end of January, practically in working order again.

The measuring machine which is being made by the Cambridge Scientific Instrument Company is approaching completion.

Northumberland Equatorial.—With a 5-inch portrait lens attached to the instrument a number of photographs for measurement were made of comet Swift 1899.

Extensive preparations were made to observe the *Leonids*, and we shared the general disappointment. Twenty-one plates of the region about the radiant point were secured with the portrait lens, and a preliminary examination shows only one trail. Visual observations gave 150 meteors distributed over twelve hours of clear or partially clear weather on the nights of November 13, 14, 15; and a number of trails were plotted. Twelve members of the University assisted in this work.

Observations of the partial eclipse of the Moon, 1899 December 16, were stopped by clouds shortly after first contact with the shadow.

The Newall Telescope, Cambridge Observatory.

The Newall telescope was used for observations on 110 nights in the course of the year 1899, as compared with eighty-five nights in 1898 and with eighty-two nights in 1897. The atmospheric conditions have for spectrographic purposes been much better than in the three preceding years.

In the first half of the year the instrument was used in connection with the Bruce spectroscope in taking photographs of stellar spectra for the determination of velocity in the line of sight. Before July 24, eighty-eight photographs suitable for measurement had been obtained, giving material for the determination of velocity for thirty-one stars.

The Bruce spectroscope was dismounted 1899 July 24, it having been decided for various reasons that the set of observations for which the instrument was designed should be brought to a conclusion. The present seems to be a fitting opportunity for giving a brief summary of the work done with the instrument. The Bruce spectroscope (single prism) was ready for work in the late autumn of 1895; and in the course of the next twelve months more than 200 photographs of stellar spectra had been obtained. The discussion of the results of the measurements showed, however, that there were more or less systematic differences between the velocities determined at Cambridge and those at Potsdam and elsewhere. This led to the discovery of a defect in the instrument, in consequence of which a minute deflection of the collimator had been produced every time the reflecting prisms for photographing the comparison spectra were used. It was accordingly found necessary to reject nearly 150 photographs of stellar spectra as valueless for the determination of the velocity in the line of sight. The defect in the instrument was remedied in 1897 February, and since that date 340 photographs of stellar spectra have been obtained, affording material for determination of velocity for eighty-five stars in all. Of these, thirty-five stars are included in the Potsdam list of fifty-one stars. Thus fifty additional stars of magnitude between 2.0 and 4.5 will be dealt with; it is, however, anticipated that it will not be possible to deduce trustworthy velocities for all of these, because certain of the spectra have indistinct lines, such as are seen in the spectra of α *Aquilæ* and β and δ *Leonis*. In addition to many other stellar photographs taken, but rejected as faulty or insufficiently exposed, 461 photographs have been taken with the instrument in the laboratory and in the observatory, either for testing the adjustments of the spectroscope or in connection with investigations of special points arising in the course of the study of the stellar spectra.

The measurement and reduction of the photographs, and the discussion of results, have proved more troublesome than was anticipated, chiefly on account of the fact that different methods

had to be found for spectra of type other than solar. Reference was made in last year's report to the development of another method of reduction. This method is applicable to spectra of all types, and has been in use for the last fourteen months. It is nothing more than the most direct determination of wave-lengths of the stellar lines in terms of the comparison spectrum of the iron spark. The wave-lengths thus determined are affected by velocity, which can at once be deduced when the lines have been identified with the lines of known elements, and consequently of known wave-length. The relation used for the interpolation of wave-lengths is the old relation first used by Cornu, by the revival of which Hartmann of the Potsdam Observatory has done such good service—viz. $\lambda - \lambda_0 = c/(R_0 - R)$. In April a Brunsviga calculating machine was pressed into the service, and proves even more satisfactory than was anticipated.

The measurement of the photographs of this series is temporarily interrupted pending the arrival of a new micrometer, with which it will be possible to measure a much longer range of the spectrum, and consequently to obtain a greater choice of suitable lines than heretofore. Meanwhile, the old micrometer is being used in other measurements.

Within five days of its being dismounted, the Bruce spectro-scope (single prism) was converted into a four-prism spectro-scope, preparation having been made beforehand to attach the strong cast-iron prism-box with four prisms, which had been made for use in the Indian eclipse of 1898.

During the last five months of the year sixty-six photographs have been obtained of the spectra of bright stars with this powerful instrument. The scale of the spectra is approximately 1.5 tenth-metre per revolution of the micrometer, or about 6 tenth-metre per millimetre. These are obtained with a camera whose effective focal length is about 1,000 mm., and whose aperture is $f/20$; and in spite of the fourteen inches of glass in the total base of the prisms, sufficient light gets through the prisms in about an hour's exposure to give spectra of the brightest stars of density enough for accurate measurement. (With a camera of focal length about 500 mm. and aperture $f/10$, the spectra obtained show admirable definition, and when the present investigation is completed the instrument will be used with the shorter camera for fainter stars.) Spectra of twelve out of fifteen stars on the working list have been taken, and one of the first results obtained with the instrument is the discovery of the binary character of α Aurigæ, which was lately announced (*ante*, p. 2). Twenty-three photographs of the spectrum of this star have been secured, and the preliminary measurements with a micrometer of small range seem to show that the period of the new binary is 104 days.

Dunsink Observatory.

Up to September systematic observations have been made with the meridian circle in order to determine the positions of stars of reference for star clusters, and, at Dr. Gill's request, the positions of stars of reference for the major planets. The number of observations is 2399, including 79 of collimation error, 81 of level, 15 of the error of runs of the microscopes, and 69 of the nadir point. Sixty-three transits of polar stars were also observed for determining the azimuth, 304 transits of standard stars for the error of the Dent sidereal clock, and 284 zenith distances of standard stars for the equator point. The observations of stars on the working list amount to 1046 in R.A. and the same number in Declination.

The interval from September to the close of the year has been occupied in preparing these observations for press. This work will be published as Part IX. of the *Astronomical Observations and Researches made at Dunsink*. It will contain the results of observations of 321 stars, from an average of four observations for each star. As already stated, the stars are reference stars for clusters, together with some other stars observed at Dr. Gill's request.

The Roberts' Equatorial has been used chiefly in photographing clusters of stars. The number of plates taken during 1899 is 116.

Observation of the partial solar eclipse in June and of the lunar eclipse in December was impossible, the sky being quite overclouded on both occasions. A watch was kept continuously for three nights and for part of a fourth in the hopes of seeing or photographing the *Leonids*. Only two or three meteors were seen, owing to the unfavourable weather.

As usual the time service to Dublin has been kept up, a time-ball being let fall daily at 1^h G.M.T. The usual facilities have been allowed to visitors.

Durham Observatory.

We have to record the decease of Mr. H. J. Carpenter, who had filled the post of Observer for fourteen years. He resigned the post shortly before his death.

Mr. F. C. H. Carpenter, formerly of the University Observatory, Oxford, has been appointed Observer.

During the year the house for the Almucantar has been built, on a spot a little to the S.E. of the old buildings; Messrs. T. Cooke & Sons have completed and delivered the instrument, and it will be erected in the course of a few days. Tables have been computed to facilitate reduction of its observations.

Professor E. C. Pickering having kindly communicated to the

Director his photometric observations of *Jupiter's* fourth satellite, an extensive piece of work has been begun in discussing these. Provisional corrections to Damoiseau's Tables of IV. have been deduced, showing large and well-marked errors, amounting to several minutes of time.

Watch was kept for the *Leonids*, and an attempt was made to enlist the co-operation of observers in scattered positions over Yorkshire, Durham, and Northumberland. The result is published in *M.N.*, 1899 December.

Meteorological observations have been continued as usual.

Glasgow Observatory.

The transit circle was used during the year for the observations of the star *BD 89° 37*, and of α and λ *Ursæ Minoris*, in continuation of the work which was begun three years ago. The rectangular coordinates of *BD 89° 37*, which has at present a polar distance of $7'$, are measured in a bright field by means of the two micrometers of the instrument at intervals of about three hours. Each night's observations determine the coordinates with reference to the pole, and the adjustment with reference to the vernal point alone requires the knowledge of approximate sidereal time. The errors of the instrument are derived from the same observations, allowance being made for their changes during a night as found from settings on the collimators, nadir and azimuth mark. The coordinates are therefore fundamental and well suited for the determination of the constant of aberration, and the motion of the pole, independent of the change of latitude. Unfortunately the weather again proved adverse to the work. Although time observations were possible on 142 nights, there were only thirty-eight nights during the year, April excepted, on which observations of faint objects could be carried on. Twenty-six nights were devoted to the transit circle, but only on sixteen nights could two or more observations of *BD 89° 37* be obtained. The instrument was reversed in its bearings twelve times. The distortion of the field was derived from transits of λ *Ursæ Minoris* over the whole field, the error being about $0''.3$ at a distance of $8'$ from the centre. In recent years the division errors of the circle had been determined for each degree line. This investigation was extended to each $2'$ line, which may come, for pole stars, under one of the eight microscopes in the two positions of the circle. Twenty-four degrees were measured. The reductions brought out the fact, which perhaps belongs to all circles made by Ertel, that the division errors repeat for each of the degrees. If one assumes that after the degree lines were marked, the minute lines were filled in by being copied from the same standard scale, the average error of copying works out to $0''.30$, while some of the individual division errors amount to four times that quantity; for

instance, the average difference of the corrections of the 18' and 16' lines is $+1''.18$, and of the 20' and 18' lines $-1''.17$, and the twenty-four determinations made all over the circle differ from these only by $0''.3$ on an average; and so it follows that the position of the 18' line of the standard scale was $1''$ out. It is apparent that these errors systematically affect the declination of a star during a number of years, if only the errors of the degree lines were taken into account.

The "Breadalbane" reflector, with its spectroscope, was principally employed on the *Orion* and *Andromeda* nebulae. The observations with this instrument had to be interrupted during the summer months of the year, on account of the definition of the large prism being impaired by the great changes of temperature in the dome after a sunny day. In October a plate was exposed on the spectrum of the *Andromeda* nebula, and re-inserted into the camera on every clear night. For this purpose the plate-holder carries an eyepiece with cross wires, and is capable of adjustment in the camera by means of two delicate screws. The fiducial point is given by a line of the spectrum of magnesium. Until the end of the year there were only five clear nights, which yielded a total of twenty-two hours. As it is not expected that less than 100 hours will suffice, the plate will probably be lost. A fresh attempt will be made next autumn.

A look-out was kept for the *Leonids* on November 14 and 15 until daybreak. On the first date it was clear after midnight, and twenty-one meteors were counted at regular, but not uninterrupted, watches. A distinct increase in the numbers occurred between 5 and 6 A.M. On the second date only a few were seen on a hazy sky, which became overcast soon after midnight.

The time service and the extensive meteorological work have been carried on as in former years.

Liverpool Observatory.

The character of the work pursued at the Liverpool Observatory has not altered from that of previous years. The Dock Board keep steadily in sight the desirability of making the Observatory useful to the requirements of the Port, and consequently the distribution of time signals, and the examination of nautical instruments deposited for the purposes of examination and correction, form a large part of the routine work of the Institution.

The transit instrument and equatorial are maintained in efficient repair and constant use. An examination of the behaviour of the level and azimuth errors of the former, to which reference was made in the last annual report published by the Board, has been extended so as to embrace several years, and the existence of an annual period of considerable amount is still further disclosed. Some attempts have been made to detect a diurnal period, but various circumstances have combined to defeat a rigorous inquiry of this character. The observation

of certain circumpolar stars suggested by Professor Auwers is, however, still continued in the hope that they may eventually be useful for this purpose.

The Equatorial is used for the observations of comets, of occultations, and for the measurement of the diameter of planets. The low altitude of *Jupiter* and *Saturn* has, however, much interfered with the prosecution of this last inquiry, and some of the anomalies which have been detected while employing various micrometers and with different illuminations still remain unexplained. With the view of still further examining the micrometers and eliminating the question of artificial illumination, a series of measurements has been commenced on *Venus*.

Arrangements were made for observing and photographing the anticipated *Leonid* shower; these were defeated by the weather and the paucity of the meteors.

The seismological observations are still continued. By the kindness of the Earthquake Committee of the British Association, a second bifilar seismograph has been added to the equipment, which will be placed to register disturbances in a plane at right angles to that previously used. Some necessary alterations and additions are still being made to this instrument, but it is hoped shortly to continue the inquiry, which has been interrupted pending the erection of the second instrument.

The meteorological observations, of which the results are forwarded to various local authorities, are carefully maintained. Hitherto it has only been possible to secure hourly records of pressure, wind, and rain, no provision being made for the automatic registration of changes of temperature. This defect is now being removed by the erection of a self-recording hygrometer, funds having been voted by the Marine Committee for that purpose. The Dines Anemometer appears to work satisfactorily, but the disagreement between its records and those of the well-known Osler type is as marked as in previous years.

Radcliffe Observatory, Oxford.

The observations with the transit circle during the first three months of the year were carried on with vigour; and during this period, owing to the unusual succession of cloudless nights, the number of transits observed amounted to 1269, and the North Polar distances for the same period to 1057. On March 29 Mr. Rudolf Grubb arrived to set up the new chronograph, and from April 1 it became necessary to discontinue regular observations owing to experiments with the standard clock. The movement of this clock was, on May 3, sent to Messrs. E. Dent for a new attachment of contact springs for registration of the seconds upon the barrel of the chronograph. This work and various experiments for the adjustment of the registering apparatus

lasted intermittently till June 7. Good progress was made from June till September with stars in the working list.

In October it was decided to undertake the reduction of Dr. Hornsby's observations made at this Observatory in the year 1774 with Bird's transit instrument and quadrants, and for this purpose all observations were stopped, so as to put the whole strength of the staff into the work. The observations of that year (1774) have been reduced as a specimen, to enable a judgment to be formed of the value of the enormous mass of unpublished observations made at this Observatory by Dr. Hornsby and his successors, with the same instruments, between the years 1774 and 1838. The results have been communicated to the Society (*ante*, p. 265), and are of a very striking character. The mean error of an observation in R.A. is only $\pm 0^s.08$, as compared with $\pm 0^s.21$ found by Bessel for Bradley's observations.

Notwithstanding these interruptions, the total number of observations made with the transit circle amounted during the year to 2664 in R.A. (including 91 of the Sun and 24 of the Moon), whilst the N.P.D.'s amount to 1957 (including 88 of the Sun and 25 of the Moon). The nadir and level were observed 119 times.

As parts of the working catalogue had been worked out, the whole has been revised and many additions made. It now contains all stars down to the 7.3 magnitude between $+5^\circ$ and 0° decl.; some stars with large proper motions, and, in areas where brighter stars did not exist, some of fainter magnitude than 7.3 have been inserted.

All the Zodiacal stars in the working catalogue, which had been inserted from Dr. Downing's list, have now been observed; but the reductions are in a backward state, owing to the many other branches of work which have engaged our attention.

With the Barclay equatorial several observations of comets, nebulae, and variable stars have been made, the results of which, in some cases, have been already communicated to the Society.

The observations of the *Leonids* on November 14, and the result of the watches on November 15, have been communicated to the Society.

The printing of the results of the Radcliffe observations made in the years 1890-91 has been completed, and the volume was distributed during the summer.

The meteorological observations and automatic registrations have been maintained as usual during the year.

The underground platinum resistance thermometers have worked very satisfactorily. Readings of the five thermometers buried in the soil at depths of 6 in., 1 ft. 6 in., 3 ft. 6 in., 5 ft. 10 in., and 10 ft. respectively, and of a similar one "A" suspended in air in the observing room, have been taken every day and reduced to the air scale. In October thermometer "A" and the upper one of the buried instruments were carefully re-standardised; and as the fundamental points were found to have remained

practically stationary during the year elapsed since their previous standardisation (the greatest difference being $0^{\circ}03$ C.), it was not thought advisable to go to the labour of exhuming the deeper ones for the present.

The erection of the chronograph has already been referred to. This instrument is of Sir Howard Grubb's latest pattern. It consists of two barrels nine inches in diameter (so that a second space is very nearly half an inch long), with a driving clock electrically controlled by the sidereal standard. Each barrel runs for $4^h 50^m$. The contact in the clock is made by a special wheel of sixty teeth (with one removed) attached to the escapement arbor. This instrument is found to work very satisfactorily.

Several alterations and improvements have been made to the transit circle. A new clamp and slow motion apparatus has been fixed to the cone of the eastern axis of the telescope, by which arrangement the clamp acts directly on the axis. The clamp is firm, and the slow motion is smooth and convenient.

On November 20 the new eyepiece and breech end for the transit circle, which had been in course of construction by Mr. Simms during the last twelve months, were brought to Oxford, and, during the next week, were fitted to the instrument. The breech end contains several improvements on the old pattern. The eyepiece is moved by screws in both directions; there is an adjustment by means of opposing screws both in focus and position angle; and the readings of the micrometer in N.P.D. are embossed on a paper strip by simple pressure of a screw, and can be read off at leisure and kept for reference. The bright wire illumination is effected by Abbé's method.

The effects of these alterations are being tested. It is also proposed to examine the form of the pivots at an early date, and a special apparatus for this purpose is now almost complete.

Early in the year the Radcliffe Trustees decided to set up a large equatorial refracting telescope, with an object glass of 24 in. aperture and 22 ft. 6 in. focal length for photographic work, and an object-glass corrected for visual rays of the same focal length and 18 inches aperture, to be used as a guider to the former. The mounting is to be of Sir H. Grubb's standard pattern, but modified so as to give complete circumpolar motion up to the zenith. The driving clock will be of the same pattern and size as that of the 26-inch at the Royal Observatory, Greenwich. The 18-inch telescope is to be fitted with two breech-pieces—one furnished with the ordinary slides at right angles to each other, to be used when the instrument is acting as a guider to the 24-inch, and the other furnished with a position micrometer for independent visual work.

The instrument is to be placed in a new tower, at present in process of erection, of thirty-one feet internal diameter. The dome is to be of steel and papier-maché of thirty-two feet diameter, with Grubb's new pattern live ring, and Gill shutter ten

feet wide at the base, and will be furnished with a lifting floor, raised by hydraulic pressure.

The discs for the two telescopes have been received some months ago from M. Mantois ; and Sir Howard Grubb reports, as the results of his first trials, that they appear to be exceptionally good.

The construction of the mechanical parts is in a forward condition.

University Observatory, Oxford.

The present main work of the Observatory is the measurement and reduction of 1180 plates in zones $+25^{\circ}$ to $+31^{\circ}$, according to the scheme of the International Astrographic Conference of 1887. To this work it was decided to devote five years, and application was made to the Government Grant Committee for 750*l.* in five instalments of 150*l.*, of which four instalments have been received. About three and a half years' work of the five has been done, and 506*l.* paid to the computers temporarily engaged. This amount expended is 0.674 of the total estimate, and should accordingly represent 795 plates completed. Actually, 645 are completely measured and reduced, forty-nine are measured and partly reduced, and there is other work in hand in the shape of preliminary reductions. We are thus a little, though not much, behind on the estimate, which was necessarily a rough one. Two or three computers have been employed at the Observatory during the year, and Mr. T. J. Moore has continued measuring at his home near Doncaster with an instrument lent him by the Observatory.

Altogether 103,000 measures have been made during the year, 50,000 of them by Mr. Moore. Since each plate is measured twice this means 51,500 star positions, or about 20,000 separate stars. The number of plates measured was 211, giving an average of 244 stars per plate, which shows that the steps taken to reduce the work within reasonable limits have been successful ; see reports for previous years.

During the year 179 plates were completely reduced. At the end of the year zones $+25^{\circ}$, $+26^{\circ}$, and $+27^{\circ}$ were so far completed that only 11, 24, 32 plates respectively, out of totals of 180 each, yet remain to be finished.

The ledgers of Oxford places for the stars observed on the meridian at Cambridge have been kept up, and have recently afforded material for a discussion of "Magnitude Equation," or change in personal equation with stellar-magnitude (see *Monthly Notices*, lx. p. 3). It is made clear that this change is real and sensible, and can be readily measured in this way. Six other papers have also been communicated to the Society by the Professor or by Mr. Bellamy on topics connected with this work, and arising out of it. A discussion of possible optical distortion

on plates of much larger (celestial) area, taken with a doublet at Harvard, seems to show that such distortion is very small; and the question arises whether it is advisable to take "Chart" or long exposure plates on so small a scale as $2^\circ \times 2^\circ$, when the labour and time of taking them can be so enormously diminished by using instruments which will cover larger fields. This investigation is still proceeding.

One of the micrometers has been lent at times during the year to Mr. S. A. Saunder, for the measurement of lunar photographs kindly supplied by M. Loewy.

Mr. A. J. Walker, M.A., of New College, determined the geodetic position of the University Observatory with reference to the Radcliffe Observatory in May last (*Monthly Notices*, lix. p. 557).

Mr. F. C. H. Carpenter, who was appointed second assistant at this Observatory at the beginning of the year, left to become assistant at the Durham Observatory on September 30. Mr. H. F. Mullis has recently been appointed second assistant.

The usual lectures on Mathematical Astronomy were delivered during the year, and attended by about a dozen students.

Temple Observatory, Rugby.

The educational work of this Observatory has been continued as usual, and the interest taken by boys has been greater than in former years. The measurement of double stars has formed the work at the Observatory during hours not devoted to teaching. After a year's absence, owing to ill-health, Mr. Atkinson has returned to the Observatory.

Stonyhurst College Observatory.

The solar surface drawings in 1899 number 183, on as many days. Of these, 128 sheets are drawings of spots and faculæ, and the remaining 55 show only small spots as dots, and some faculæ. The mean daily disc-area deduced from the whole number of drawings is 0.7 units,* against 2.5 of the preceding year; and, dividing the year into two parts, January 1—July 16, and July 17—December 31, the mean areas are 1.1 and 0.2 respectively; which seem to indicate a close approach to the minimum period at the end of the year 1899.

Comparing the magnetic disturbances with the solar spot area, it may be remarked that of the seven days in the year noted for greater magnetic disturbances, four occurred in the two periods of greatest spot areas of the year, in the middle of March and at the end of June, and the remaining three occurred in the very quiet periods of solar activity in January, February, and May.

The grating spectrographs of the HK region of the solar

* $\frac{1}{5000}$ th of the disc area.

spectrum number 162 on eighty-one days. On sixty-seven of these days the photographs are strong enough to show the intensities of the reversals. There is no marked difference between the results of this and the preceding year; but both collections are waiting for comparison with similar plates of a future period of greater solar activity.

Considerable preparations were made for the possible *Leonid* meteor shower. Five cameras were mounted for the meteor streaks; and one was attached to the eye-end of the Perry Memorial telescope with the hope of obtaining a photograph of the meteor swarm as a cluster or comet outside our atmosphere. This camera was the chief hope of the watch on the morning of the 16th, for which Dr. Johnstone Stoney had kindly provided the position for the sight-line-tangent to the meteor path. Unfortunately the sky, though clear enough for eye observation of meteors to the third magnitude, was too hazy for the feeble light of the distant swarm. Only a few *Leonids* were seen on the morning of the 16th, and the preceding nights, from the 10th to the 14th inclusive, were cloudy throughout.

The stellar spectrograph has been employed on all available nights, to continue the series of photographs intended for investigation of possible changes in the spectra of selected stars. But the work of measuring and mapping these has been interrupted by a corresponding work on the solar drawings of the last nineteen years.

Markree Observatory (Colonel Cooper's).

During the year 1899 the regular meteorological work of the Observatory has been carried on as usual, and the weekly and monthly returns have been made to the Meteorological Office, the Registrar-General at Dublin, &c.

Some observations have been made with the unifilar magnetometer and the dip circle; but the magnet house not having been yet erected, only preliminary work has been attempted.

The great telescope was unfortunately injured in the storm of January 12, and the damage done not being repaired till the end of August, the instrument has only been used for a small part of the year. Some use has been made of a smaller instrument, and observations for the determination of local time have been regularly made with the meridian circle.

A few visitors have called at the Observatory, and some returns of the rainfall have been made in connection with proposed hydraulic engineering work in the neighbourhood.

The library is now in fair order and has been enriched by valuable presents during the year, for which best thanks are due to the donors.

A watch was made for the *Leonids* during several nights, but the sky was almost completely overcast, so that none were

certainly seen, although a few were reported to have been seen from Sligo on the early morning of November 15. The lunar eclipse of December 16 was for the same reason unobservable. The month of December 1899 was perhaps that of the greatest rainfall for many years.

Mr. Edward Crossley's Observatory, Bermerside, Halifax.

Astronomical and meteorological observations have been carried on as in past years. The phenomena of *Jupiter's* satellites, and the physical features of *Jupiter* and *Mars*, have been carefully and regularly observed; the results have already appeared in the *Monthly Notices*. The usual 9 A.M. and 3 P.M. meteorological observations have been made, and reports or summaries sent to the Registrar-General, Mr. Symons, local newspapers and occasional applicants.

Wolsingham Observatory (Rev. T. E. Espin's).

The work has been carried on as in previous years. The results of the sweeps are as follows :—

Stars of type IV.	...	...	...	...	5
„ „ III.!!	III.!!!	...	...	...	86
„ „ II.	III.!	...	...	...	155
Known stars observed	...	...	...	...	126
New nebulae	...	...	...	...	6

Various plates have been obtained with the 8-inch photographic telescope, and in the latter part of the year measures have been made of some double stars and some new pairs.

Sir William Huggins's Observatory, Tulse Hill.

The photography of the spectra of stars, which has been in progress for some years, has been continued.

Special work has been done in the laboratories in connection with the completion of a volume of publications of this Observatory, which is just ready, and of which the principal contents are an Atlas of representative stellar spectra from λ 4870 to λ 3300; together with a discussion of the evolutionary order of the stars, and the interpretation of their spectra; preceded by a short history of the Observatory and its work.

Rousdon Observatory (Lyme Regis), Devon
(Sir Cuthbert E. Peek's).

The building and equipment of the Observatory have been maintained in their usual order. November was an abnormally cloudy month, the rest of the year was generally favourable, and observations were made on 167 nights, this being about the average. The 6·4-inch Merz equatorial has been kept at the regular observation of long-period variable stars; Argelander's method was followed as during the previous thirteen years. Five hundred and seventy magnitude determinations have been made, being in excess of any previous year's work. Seventeen maxima and twenty-two minima have been observed. As most of these variables at minima are very faint objects, and as several fall below 13·5 magnitude, thus being beyond the range of this telescope, the observations have been very difficult. About twenty-five variables of long period are under regular observation; these being mostly circumpolar, the light variations are continuously recorded.

Variable Star Notes No. 4, containing observations of *R Cygni* and χ *Cygni* for the ten years 1887 to 1896, and *Variable Star Notes* No. 5, containing observations of *U Orionis* and *S Herculis* for the thirteen years 1886 to 1898, have been published and distributed. The results are given concisely in tabular form, accompanied by diagrams of the light curves.

Variable Star Notes No. 6 is far advanced, and will appear shortly.

Transits of stars have been taken as often as required for the timing of the sidereal clock, which has maintained a very steady rate.

Birr Castle Observatory (the Earl of Rosse's).

During the past year determinations of the Moon's radiant heat have been continued at intervals, in order to arrive at a better phase-curve than had up to the present been found possible, but the difficulties arising from climatic and other causes make our progress extremely slow.

It has also been necessary to wait for lunar eclipses to clear up uncertain points. Some determinations made during the eclipse of 1898 December 27, now being reduced, will be, owing to clouds, necessarily of inferior value to those obtained on previous occasions. "Near approaches" were watched for on 1899 January 26, April 25, July 22, and October 18, but without success, owing to the same cause. The same may be said of the eclipse of December 16.

Some photographs of nebulae have been taken, but the results have not been as satisfactory as might have been expected, from causes which would take too long to explain here.

Meteorological observations have been continued as usual.

The *Leonid* meteors were watched for, but fewer than usual seen when occasional breaks in the clouds rendered this at all possible.

Dr. Isaac Roberts's Observatory, Crowborough Hill, Sussex.

The second volume of photographs of *Stars, Star-clusters, and Nebulae*, to which reference was made in my report to the Council in February last, is now printed; and before this report is read about one hundred copies will have been presented to a select number of public Observatories, Institutions, Societies, and to some astronomers.

Attempts were made in November and December to photograph the *Leonid Meteor Stream*, the positions of which were given in the *Ephemeris* furnished by Dr. G. Johnstone Stoney and Dr. Downing, aided with the grant made by the Royal Society; the computations for which were made by Mr. Thomas Wright, of the staff of the *Nautical Almanac Office*.

Two opportunities occurred that were suitable for taking photographs. The first on November 6, when plates were taken with an exposure of ninety minutes; the second on November 8, with an exposure of two hours and fifty-five minutes. Three photographs were taken simultaneously on each occasion: one with the 20-inch reflector, one with the Cooke 5-inch lens (aperture to focus 1 to 3·84), and the other with a Voigtländer lens (aperture 1 to 2·2); but on none of these six photographs was there any indication of the presence of the meteor stream.

Close watches were also kept on the sky each night and morning between 11 P.M. on November 14 and 5.30 A.M. on the 17th, with the object of finding an opportunity for photographing the meteor trails as they would be formed in the atmosphere; but the sky was either continuously obscured by clouds, or else with a few clear openings of short duration. No chance for obtaining a photograph occurred during those four days; consequently all the attempts were failures.

The selected photographs of celestial objects referred to as follows have been taken during the past year; which, like most of the preceding years, has generally been unfavourable for photographic work.

List of the principal Photographs taken in 1899.

	R.A.	Decl.	Expos.
	h m	° ' "	h m
H's Nebulous Region No. 2	... 0 17	+ 3 59	1 30
" " " " 3	... 0 22	+ 29 0	1 30
" " " " 6	... 0 36	+ 0 29	1 30
Neb. M. 31 Andromedæ ...	... 0 37	+ 40 43	1 30 (three)
Neb. H. V. 1 Ceti ...	... 0 42	- 25 51	1 30 (two)

		R.A. h m	Decl. ° ' "	Expos. h m
Neb. near γ Cassiopeiæ ...	...	0 50	+ 60 11	1 30
Neb. M. 33 Trianguli ...	...	1 28	+ 30 8	1 30
Nebulosity in Pleiades region ...	...	3 44	+ 25 16	2 58
Neb. ζ I. 258 Persei ...	...	3 55	+ 51 1	2 52
Hind's neb. in Taurus ...	...	4 16	+ 19 17	1 30
Neb. ζ I. 122 Eridani ...	...	4 36	- 3 3	2 54
Neb. ζ V. 32 Orionis ...	...	5 1	- 3 30	2 20
Neb. ζ V. 38 Orionis ...	...	5 21	- 8 13	1 30
Neb. N.G.C. 2237 &c. Monocerotis ...	6 25	+ 5 0	1 30	2 45
New Nebula in Monoceros ...	7 0	- 10 20	2 47	
Neb. ζ V. 21 Canis Majoris ...	7 12	- 13 1	1 30	
Cl. M. 67 Cancri ...	8 45	+ 12 13	1 0	
Neb. ζ I. 72 Ursæ Majoris ...	10 23	+ 30 2	1 30	
Neb. ζ I. 81 Leonis ...	10 38	+ 25 29	1 30	2 47
Neb. ζ V. 52 Ursæ Majoris ...	10 40	+ 63 47	1 30	
Neb. ζ I. 172 Ursæ Majoris ...	10 46	+ 37 11	1 30	
Neb. ζ I. 87 Leonis Minoris ...	10 54	+ 29 33	2 40	
Neb. ζ I. 194 Ursæ Majoris ...	11 20	+ 44 10	2 47	
Neb. ζ I. 203 Ursæ Majoris ...	11 47	+ 44 43	2 32	
Neb. M. 99 Virginis ...	12 13	+ 14 58	1 30	
Neb. M. 61 Virginis ...	12 16	+ 5 3	2 3	
" Leonid " meteor swarm ...	13 10	+ 9 38	4 0	
" " " ...	13 16	+ 8 37	2 0	
Neb. ζ I. 170 Boötis ...	13 41	+ 42 15	1 30	
Neb. ζ I. 180 Boötis ...	13 42	+ 44 22	1 30	
Neb. ζ I. 181 Boötis ...	13 53	+ 42 22	1 30	
ζ 's Nebulous Region No. 40 ...	14 2	+ 34 8	1 30	
Neb. ζ I. 214 Ursæ Majoris ...	14 2	+ 54 40	1 30	
ζ 's Nebulous Region, No. 41 ...	15 9	+ 18 57	1 30	
Neb. ζ II. 759 Draconis ...	15 13	+ 56 43	2 0	
Neb. ζ I. 148 Scorpii ...	15 17	+ 5 27	2 0	
Cl. M. 80 Scorpii ...	16 11	- 22 43	1 30	
Cl. ζ VI. 40 Ophiuchi ...	16 26	- 12 50	1 0	
Neb. ζ I. 280 Ursæ Minoris ...	16 38	+ 78 25	2 0	
Neb. ζ IV. 41 Sagittarii ...	17 56	- 23 2	1 30	
Neb. M. 8 Sagittarii ...	17 57	- 24 23	1 30	
Neb. M. 17 Clypei ...	18 15	- 16 13	2 18	
Cl. M. 22 Sagittarii ...	18 30	- 24 0	1 30	
Neb. M. 27 Vulpeculæ ...	19 55	+ 22 26	0 50	
Cl. M. 75 Sagittarii ...	20 0	- 22 13	1 0	
Cl. M. 73 Aquarii ...	20 53	- 13 2	1 0	
ζ 's Nebulous Region No. 47 ...	21 5	+ 14 21	1 30	
Cl. M. 2 Aquarii ...	21 28	- 1 16	1 18	1 30
ζ 's Nebulous Region No. 49 ...	21 47	+ 21 31	1 30	

*Mr. W. E. Wilson's Observatory, Daramona, Streete,
co. Westmeath.*

During the past year the 24-inch reflector has been used almost entirely for stellar photography. During the summer one of Ångström's pyrheliometers was ordered from Messrs. Sandström, of Lund, but was not received until late in the year. From a few observations taken with it in December, the instrument seems to give very concordant results of the value of solar radiation in absolute units.

Hong Kong Observatory.

Hourly meteorological observations, weather reports, storm warnings, magnetic observations, tabulation of meteorological logs kept over the eastern seas, the time service, &c., were continued as in previous years. Variable stars, shooting stars, and the Zodiacal Light were only occasionally observed. About 5000 transits were observed.

The re-reduction of Sir J. Herschel's sequences of southern stars was finished, and we now possess a catalogue of accurate magnitudes of 918 stars for 1837. Very few observations of known variables are included. The probable error of an observation of a star of the 2nd magnitude is ± 0.075 ; of the 3rd, ± 0.087 ; of the 4th, ± 0.121 ; and of the 5th, ± 0.204 .

A star of the 1st magnitude was on an average observed 11 times by Sir J. Herschel, of the 2nd 8, of the 3rd 3, of the 4th twice, of the 5th $1\frac{1}{2}$ times, and of the 6th only once.

The Madras and Kodaikānal Observatories.

On April 1, the beginning of the Indian financial year, the reorganisation of the Madras Observatory, which has for some time been decided upon, took effect. The Observatory, which has ever since its foundation in 1792 been directly under the Madras Government, was handed over to the Government of India, and the former "Government Astronomer" became the "Director of the Kodaikānal and Madras Observatories." At the same time the headquarters of the Director were transferred to Kodaikānal, and the Madras Observatory was placed under the charge of Professor R. Ll. Jones as Deputy-Director.

Advantage was taken of the dry weather of the first three months of the year to move up to Kodaikānal the instruments and the astronomical library—a matter of no small difficulty, since for ten miles of the road everything had to be carried by coolies up a steep and narrow path. Including furniture, more than 1000 coolie-loads were brought up.

Almost the whole of the Director's time during the past year has had to be devoted to matters concerned with the new buildings. At the close of the year both domes were erected and the 6-inch equatorial was in place, though not finally adjusted. Much work yet remains to be done on the buildings, and at the present rate of progress it will be several months before the workmen have finished the main building.

No astronomical observations, except those on the *Leonids*, have been attempted during the year at Kodaikānal, but the printing of the star catalogue has been completed, and the volume should be ready for distribution in a few days. Meteorological observations were begun on April 1, and have been continued regularly.

At Madras the usual time observations and distribution of time signals were continued, as well as the meteorological observations.

Melbourne Observatory.

Meridian Observations.—These were made with the 8-inch transit circle. The table below shows their distribution :—

Observations in				R.A.	N.P.D.
Azimuth Stars	...	...	...	334	168
List	„	...	...	1166	1171
Clock	„	...	...	812	...
Dr. Gill's	„	...	...	825	1010
Total	...	...	...	3137	2349

The list stars were selected from the Melbourne photographic plates of the catalogue series, and are to be used as fundamental stars for the reduction of these plates. Dr. Gill's stars are those given in his printed list of "Heliometer Comparison Stars, 1898-1900."

Astrophotographic Work:—

Chart plates with single exposure of 60 ^m ...	...	189
Catalogue plates (second series) ...	...	30
Test plates for transparency of night ...	...	48
Test plates Oxford type regions ...	...	24
Test plates for trails, centre, &c. ...	...	31

Fifteen chart plates were rejected as defective.

A second series of catalogue plates especially for zones nearer to the Pole is gradually being obtained. The series of chart plates for even degrees of declination with single exposure of one hour is very nearly complete, and we are now proceeding with the series for odd degrees of declination with three exposures of 30^m each.

With the photoheliograph 21 pictures of the Sun were taken on special occasions.

Time signals for determining the difference of longitude between Perth and Melbourne were exchanged on the night of September 28.

Only a few occasional observations were made with the great telescope and other equatorials, but no regular work was done with them.

The time service, including rating of chronometers for the shipping, &c., was carried on as in former years.

The meteorological service has been the great burden of the Observatory, and is continuously increasing. The number of recording stations in the Colony of Victoria is now about 600.

The photographic registration of the variation of the magnetic elements and their absolute measurements, cloud photography for the determination of height and velocity of clouds, and the testing of meteorological and nautical instruments for the public, have formed part of our routine work during the year.

Three hundred and eight visitors were shown over the Observatory on Wednesday afternoons, and 248 were admitted on specially appointed nights.

Five young computers were employed in the course of the year in measuring and reducing magnetic curves and cloud photographs, and in preparing the third Melbourne General Catalogue of stars for the epoch 1890, which will contain some 3000 stars observed with the 8-inch transit circle during the years 1884-1893 inclusive.

Sydney Observatory.

In the report for 1898 it was stated that arrangements had been made for the removal of the star camera to Red Hill, 615 feet above the sea, and $11\frac{1}{2}$ miles to north-west. This work had been completed in August of this year, and since that date the instrument has been used on all available nights. As a measure of the relative clearness of the atmosphere at Red Hill and Sydney, it may be mentioned that with an equatorial of $7\frac{1}{2}$ inches diameter in use at Red Hill one can see more details of planetary markings than it is possible to see in Sydney with an equatorial of $11\frac{1}{2}$ -inch aperture.

The joint bureau for the measurement of the star plates has been established in Melbourne. (For the joint report, see next page.)

Transit Circle.—With the transit circle (one observer) 938 transits of stars and 511 meridian zenith distances have been observed, and the Sun has been observed on all available days for time, distributed by time balls and signals. Collimation level and nadir have been regularly observed, and show the regular seasonal and secular changes in the Observatory hill.

Equatorial.—With the equatorial measures of double stars have been made on eighty-four evenings; six nights were devoted

to comet observations. One hundred and twenty-nine pairs (double stars) were measured ; 114 of these are remeasurements of pairs in the Sydney lists of 1882-3. Six hundred and sixty-one settings for position angle and 662 for distance were made during the year. Twenty-five comparisons of Comet Swift were made with five stars.

Leonid Meteors.—A careful watch was kept by many observers in this colony for the November meteors, but, unfortunately, on the nights of the 15th and 16th it was densely cloudy in Sydney and greater part of this colony.

Star Camera.—The time necessarily occupied in removing the star camera to Red Hill seriously interfered with the work during the year. One hundred and fifty-three days were wet or cloudy, and 120 days were occupied in removing the instrument to Red Hill. During the year seventy-two catalogue plates and fifty-three chart plates were taken.

Publications.—During 1899 2067 copies of books and pamphlets were sent out, and in exchange 669 books and pamphlets have been received and acknowledged.

Meteorology.—Meteorology continues to demand a large part of our time. The number of observers has increased from 1610 in 1898 to 1724 in 1899.

Measurement of the Sydney and Melbourne Plates of the Astrophotographic Catalogue.

(Joint Report by the Directors of the Sydney and Melbourne Observatories.)

These measurements have been carried on at the Melbourne Observatory in accordance with the conditions, a brief mention of which was made in *Monthly Notices* for February 1898. Three measuring instruments were employed, consisting principally of filar micrometer microscopes mounted on heavy cast-iron stands, which also carry a stage for the plates, with double slide motion in two directions at right angles to each other. The resulting measures are well within the prescribed limit of error $0''.2$; but the methods of observation are excessively slow, the average number of stars measured in one position of the plate by a single observer without the assistance of a recorder being about fifteen per hour. Professor Turner's micrometer scale can be used with our present instruments instead of the filar micrometers, and with this scale some 300 stars can be measured in one day by two persons acting alternately as observer and recorder ; but in our experience the probable error of the resulting measures exceeds $0''.5$, and consequently the use of the micrometer scale was abandoned.

A measuring instrument similar to that devised by Dr. Gill for the Cape Observatory was ordered from the firm of Repsold &

Söhne early last year, and has just arrived here safely and in good order. It corresponds in all its parts to the description given by Dr. Gill in *Monthly Notices*, vol. lix. p. 61, excepting that the two slides of the micrometer carry only a pair of webs each, instead of a series of six webs for each slide, as in Dr. Gill's instrument. Nothing can be said at the present moment as to the qualities of this new machine, as there has not been time yet for careful examination and actual trial. A measuring machine devised by Mr. Russell, quite on a different principle from those we now possess, is being made in Sydney under his supervision. In all 50 plates have now been completely measured, and it is to be hoped that with the new machines good progress will be made during the current year.

Natal Observatory.

During the year the observations have been confined almost entirely to those necessary for carrying on the ordinary routine astronomical and meteorological work of the Observatory. Some observations of comets and of *Eros*, together with a number of observations of occultations during the Lunar Eclipse, were also obtained. No *Leonids* were visible.

Practically the work of the Observatory must be confined to mere routine time and meteorological observations, as since the vote assigned to the Observatory was reduced it is no longer sufficient to pay even the salaries of the assistants, the balance, together with all other expenses, having to be defrayed by the Astronomer.

During an exceptional storm in November, a portion of the library was flooded and much damage done, especially to the manuscripts. Amongst those which were seriously damaged and will have to be rewritten before being printed were our Star Catalogue, the reduction of the Greenwich Lunar Observations for 1750-1895, and the New Lunar Tables for supplementing Hansen's *Tables de la Lune*. It will take over a year to rewrite these for the press.

Perth Observatory, Western Australia.

The work of the Observatory has been so far mostly meteorological. Records of barometer, temperature, &c., have been kept at many stations throughout the colony for a number of years, and these had not been properly reduced and entered in ledgers. This work is now nearly completed; and, in addition to the current meteorological work, has occupied the full time of the staff, which is very small. The forecasts have again been very successful. Of these one is issued daily at noon, and another is contributed to the Press every evening, based upon reports

received at 6 P.M. from thirteen selected stations, and published in the daily papers. A special forecast for the Goldfields is also prepared each evening, and telegraphed to four daily newspapers on the Fields.

The percentage of success for the year was :—

	Noon.	Evening.	Goldfields.
Correct	82	89	90
Partially correct	17	11	8
Wrong	1	0	2

A local forecast for the day is issued at 9 A.M., and exhibited in a pictorial form similar to that of the London *Daily Graphic*. This is almost invariably correct.

The transit circle and astrograph are now ready for work, and observers have had a fair amount of training ; but, owing to a recent decision of the Government, it will not be possible at present to do much with them. The transit circle will be used only for time and determination of position of a guide star for each plate of the zone 17° to 23° S. Work with the astrograph will be commenced very shortly, but, owing to lack of observers, progress just at present will be slow.

Instead of taking up the zone 17° to 23° vigorously with both instruments, as the Government Astronomer hoped to be able to do, he has been instructed to defer that for the present, and to admit pupils training as surveyors or navigators to a course of practical astronomy. However, he intends, if possible, to carry on the above scheme as well, but it is a little doubtful to what extent this will be practicable.

Lovedale Observatory, South Africa (Mr. A. W. Roberts's).

The main work of this Observatory is the observation of variable stars south of -30° decl.

This work was carried on regularly during the year, the number of observations secured being as follows :—

	Stars.	Observations.
Algol variables	6	674
Short period variables	23	1873
Long period variables	74	2941
Suspected variables	10	120
Total	113	5608

The reduction of all observations taken since 1891 is being proceeded with, but the pressure of other concerns has lately hindered the completion of this task. The same circumstances have compelled the laying aside, during the past four or five months, of the magnitude survey entered upon last year.

The Director has gratefully to acknowledge the generous gift to the Observatory of an equatorial, a sidereal chronometer, and a dome from Sir John Usher, Norton, Edinburgh. The equatorial, of 2-inch aperture, is specially constructed by Messrs. T. Cooke & Sons for the visual determination of star magnitudes; a large prism in front of the object glass permits of the field under examination being rotated through any angle, and the aperture can also be "stopped" down to any size. Lord Maclaren and Dr. Gill have warmly interested themselves in the new observatory and its equipment.

*Mr. Tebbutt's Observatory, The Peninsula, Windsor,
New South Wales.*

The weather during 1899 was favourable for astronomical work. The following is the work in the meridian department for the determination of local time :—

Nights on which the time was determined	...	...	...	195
Observations of stars with a declination not exceeding 40°	...	...	...	975
Observations of stars in high declination for azimuth	...	...	...	237
Separate determinations of	{	level error	...	575
		collimation error	...	51
		azimuth error	...	170

In the extra-meridian department the following comparisons of planets and comets were made with the equatorials :—

Object.	Nights of Observation.	Number of Comparisons.	Number of Comparison Stars.
(4) Vesta	7	81	1
(7) Iris	30	380	17
(17) Thetis	16	204	3
Neptune and 114 (α) Tauri	6	80	1
Comet VII., 1898 (Coddington)...	23	152	33
Comet I., 1899 (Swift)	28	233	35
Comet IV., 1899 (Tempel ₂ , 1873)	43	413	51

The observations of Comet 1898 VII. were a continuation of the series commenced on 1898 June 15, and carried down to the close of that year. The total number of nights on which the comet was observed in 1898 and 1899 was 103, the number of comparisons being 764, and that of the comparison stars 138. Comet 1899 IV. was observed on all possible occasions at the request of M. Schulhof, of Paris. In addition to the above observations 78 phases of lunar occultations of stars were ob-

served, eighteen of them during the total eclipse of the Moon on June 23. Mr. C. T. Merfield, F.R.A.S., kindly supplied a list of occultations for the eclipse. Most of the stars were, however, taken from the Cape *Photographic Durchmusterung*, and were very faint. The same gentleman has also given an excellent ephemeris of Comet 1898 VII., and comparisons of the planet and comet places with the ephemerides. Observations of phenomena of *Jupiter's* satellites and a few measures of double stars were likewise made during the year. The meteorological observations referred to in the report for 1898 have also been continued through 1899. By comparison with former reports it will be seen that the work during the past year is quite equal to that in any former year.

NOTES ON SOME POINTS CONNECTED WITH THE PROGRESS
OF ASTRONOMY DURING THE PAST YEAR.

Discovery of Minor Planets in 1899.

Twelve new planets were discovered during the past year, as follows :—

Provisional Designation.	Permanent Number.	Date of Discovery, 1899.	Discoverer.	Place of Discovery.
EE	442	Feb. 15	Wolf—Schwassmann	Heidelberg
EF	443	" 17	"	"
EL	444	March 31	Coggia	Marseilles
EM	...	April 5	Witt	Berlin (Urania Obs.)
EO	...	July 17	Wolf	Heidelberg
ER	...	Oct. 27	Wolf—Schwassmann	"
ES	...	" 27*	"	"
ET	...	" 27	"	"
EU	...	" 31	"	"
EV	...	" 10	"	"
EX	...	" 2	Coddington	Lick Obs. (Mt. Hamilton)
EY	...	Dec. 4	Charlois	Nice

The planets provisionally designated EG, EJ, EK, EN, EP, EQ, EW, EZ were identified as follows :—

EG with (224) <i>Oceana</i> ,	EP with (32) <i>Pomona</i> ,
EJ „ (60) <i>Echo</i> ,	EQ „ (161) <i>Athor</i> ,
EK „ (222) <i>Lucia</i> ,	EW „ (110) <i>Lydia</i> ,
EN „ (85) <i>Io</i> ,	EZ „ (415).

The announcement of the discovery of EH was cancelled as erroneous.

ER has an orbit resembling those of the missing planets (99) *Dike*, (155) *Scylla*, and it may possibly be identical with one of them.

EV was at first supposed to be identical with (214) *Aschera*, which was the reason of the delay in the announcement of its discovery.

The following planets, discovered in 1898, but not numbered at the date of the last report, have since received permanent numbers : DP, 437 ; DU, 438 ; EB, 439 ; EC, 440 ; ED, 441.

The planets provisionally designated DV, DW, DX, DY, DZ, EA, EM do not receive permanent numbers, not having been sufficiently observed.

The following planets have been named : (355) *Gabriella*, (366) *Vincentina*, (387) *Aquitania*, (439) *Ohio*.

The following planets have been observed at one opposition only : 99, 132, 155, 156, 157, 193, 220, 285, 290, 293, 296, 309, 310, 314, 315, 316, 319, 320, 323, 327, 328, 330, 341, 353, 355, 357, 359, 360, 361, 368, 382, 383, 388, 392, 393, 394, 395, 398, 400, 401, 406, 408, 410, 411, 413, 414, 417, 418, 421, 422, 425, 426, 427, 428, 429, 430, 431, 432. All the other planets, from 1 to 434 inclusive, have been observed at two or more oppositions.

The planet (433) *Eros* remained under observation till May last, a period of nine months from its discovery. As it receded from the Earth, it approached the Sun, and consequently its brightness remained nearly constant during this period. Signor Millosevich has computed definitive elements from all the observations of this period, but without making use of the photographs of 1893-94, 96 (*Ast. Nach.* 3609). He deduces the following elements for the next opposition after applying planetary perturbations :—

Epoch=1900 Oct. 31^d.5, Berlin M.T.

$$\begin{array}{l} M=304^{\circ} 23' 59''.7 \\ \pi=121 \quad 9 \quad 22'.0 \\ \omega=177 \quad 38 \quad 41''.6 \\ \Omega=303 \quad 30 \quad 40''.4 \\ i=10 \quad 49 \quad 38''.9 \\ \phi=12 \quad 52 \quad 48''.2 \\ \mu=2015'''.1274 \\ \log a=0.1638027 \end{array} \left. \vphantom{\begin{array}{l} M \\ \pi \\ \omega \\ \Omega \\ i \\ \phi \\ \mu \\ \log a \end{array}} \right\} 1900.0$$

He gives an ephemeris from 1900 September 1 to 1901 January 31. It does not differ by more than 23^s of R.A., 6' of decl., from the approximate ephemeris given in the last report. He again calls attention to the fact that the large phase of the planet may cause systematic errors in parallax measures unless special precautions are taken.

The planet will be nearest to the Earth on December 26 next, when its horizontal parallax will be 27'''.9. There will not be an equally near approach for about thirty years. It is interesting

to note that *Eros* and *Mars* approached one another within a distance of 0.28 in 1899 October. This is very little greater than the least possible distance of the two planets, which is 0.24. As their synodic period is no less than 27.59 years, such a close approach is rare.

A. C. D. C.

The Comets of 1899.

In addition to several comets mentioned in the last Annual Report, observations of which were continued into the year 1899, two new ones have been discovered, and three periodical comets have been detected on their return to perihelion.

On March 3, Professor Lewis Swift, at the Lowe Observatory, perceived a fairly bright comet as it was approaching perihelion, which it passed on April 13. The position at the time of discovery and shortly after was not very favourable for observation, but after perihelion passage it attained a very considerable northern declination, and became a fairly conspicuous object. At the time of greatest brilliancy the naked eye view was not unlike that of a hazy star of the third magnitude, while in the telescope the tail could be traced for more than a degree. Photographs, however, showed this tail much longer, Professor Barnard tracing it on a plate taken on May 18 to a distance of 8° from the nucleus. The decrease in brilliancy seemed rather rapid, but by no means regular. Early in June a notable increase in lustre was announced by several observers, though the estimates of magnitude considerably differed. In the second week of May Mr. Perrine announced that the nucleus had duplicated, a fact which was confirmed by Professor Barnard, and the increase of brilliancy may very well be connected with this display of internal energy. An admirable series of photographs, showing the changes in the form and extent of the tail, was obtained at the Lick Observatory. The orbit is probably parabolic.

Dr. Wolf, of Heidelberg, detected on March 5 the trace of Tuttle's periodic comet on a photograph of the district in which the comet was known to be situated. The circumstances of the return had been computed by Dr. Rahts, and the agreement between the observed and computed place was satisfactory, considering the small number of observations that were made on the last return in 1885. On that occasion the same computer had assigned a place whose error in Right Ascension was 12^s.6, and in Declination 5'36". On the present return the discrepancy between observation and computation was 22^s of R.A. and 5' in Declination. It is to be hoped that the observations which have been made will be sufficient to give an improved value of the mean motion, but for observers in the Northern Hemisphere the comet was soon lost in the evening twilight. After perihelion (May 4), however, the comet could be observed in the Southern Hemisphere, and would be slightly brighter.

This is the fourth successive return at which the comet has been visible.

The third comet of the year was also one of the periodic class, viz. that known as Tempel's Second Comet (1873 II.). This object was detected by Mr. Perrine at the Lick Observatory on May 6. On that date the theoretical brilliancy of the comet was expressed by 0.49. In 1878, when the comet was bright enough to be seen by M. Tempel, the brilliancy was only 0.113; and in 1894, when first seen by Mr. Finlay at the Cape, the value was 0.190. The comet has always been faint, and these figures show that it tends to become fainter still. But the circumstances of the return were generally favourable for observation, and a steady increase in lustre was easily noticeable. Mr. Perrine described the object at the time of discovery as approximately of the fifteenth magnitude, but by the middle of July it was a fairly easy object in a 6-inch telescope. Dr. Wolf, who photographed the comet on the same plate with the planets *Euterpe* and *Antiope*, found the traces of the comet comparable with those produced by these planets, thus giving a magnitude of about 10.7. A short diffused tail pointed towards the North was noticed on the photographic plate.

The orbit did not suffer such great perturbation as on some previous occasions, the distance of the comet from *Jupiter* being always greater than 1.9 R. Nevertheless, the passage through perihelion was delayed fifteen days; and since the alteration of the other elements was considerable, we can heartily congratulate M. Schulhof on the accuracy of his prediction, which assigned a place to the comet differing only 6 secs. in R.A., while the error in Declination was within the errors of observation. A correction to the mean anomaly of $-24''$, or an alteration in the time of perihelion passage of less than an hour, would satisfactorily remove this small discrepancy.

Holmes' Comet of 1892 passed its perihelion passage on April 13, but was not found till June 10, when Mr. Perrine, aided by the large telescope of the Lick Observatory, added another to his many cometary discoveries. This comet, like the last, was described as of the sixteenth magnitude, and though the brilliancy was slightly on the increase, it is to be feared that not many observations have been secured. So far as at present known, the observations that have been made have been confined to the two great American refractors. Dr. Zwiers was responsible for the ephemeris which led to the detection of this interesting comet; and considering that this is the first return since the discovery, the closeness of the prediction is quite satisfactory. The period had been determined within less than half a day, giving rise to an error in the ephemeris of -22^s in R.A., and $-4'$ in Declination. It is much to be hoped that the number of observations made at this return will be sufficient to improve the theory of the comet's motion.

On September 30 M. Giacobini discovered a telescopic comet in *Ophiuchus*, moving northward. The perihelion passage had been passed on September 14, and since the distance from the Earth was also increasing, the comet remained a feeble object. The orbit will probably prove parabolic, but definitive elements are not yet known.

W. E. P.

Meteoric Observations during the Year.

The January and April meteors were not satisfactorily observed, owing to moonlight and cloudy weather. Professor Herschel, at Slough, watched on April 16, 17, and 19, but noticed little radiation from the usual contemporary showers in *Virgo*, *Scorpio*, *Aquila*, &c. There was, however, an active radiant in *Canes Venatici*.

On clear nights between May 3 and 7 Professor Herschel made observations extending in the aggregate over sixteen hours, and found radiants at $175^{\circ}+30^{\circ}$, $315^{\circ}-10^{\circ}$, and $336^{\circ}-6^{\circ}$, the latter representing the *Aquarids* and the special shower of the epoch. During the same period Mr. E. R. Blakeley at Dewsbury noted seventy meteors in watches amounting to ten hours, and derived radiants at $255^{\circ}+37^{\circ}$, $218^{\circ}+24^{\circ}$, $232^{\circ}+23\frac{1}{2}^{\circ}$, and $267^{\circ}+50^{\circ}$, but apparently registered no *Aquarids*.

August Perseids.—Splendid weather favoured views of this shower, and observations were obtained at many places on August 9, 10, 11, 12, 13, and 14. The display was not an exceptionally rich one, and certainly did not at any time equal the strength it exhibited on 1898 August 11. The hour of maximum is doubtful. Professor Herschel of Slough, and Mr. T. H. Astbury of Wallingford, recorded more meteors on August 10 than on August 11, but M. Antoniadi at Juvisy, Mr. Gregg at Malvern, and Mr. Milligan at Belfast, found the largest number visible on August 11. M. Wolf at Königstuhl, and Mr. Denning at Bristol, concluded that meteors were about equally frequent on the two nights. On August 11, from 11^{h} to $11^{\text{h}} 30^{\text{m}}$ (local time) at Belfast meteors were falling at the rate of about sixty per hour. On August 11, $14^{\text{h}} 10^{\text{m}}$ to $14^{\text{h}} 15^{\text{m}}$, Mr. King at Leicester estimated the rate at eighty-four per hour, of which sixty were *Perseids*. A large number of secondary showers became apparent during the observations. Mr. Besley, of Clapham, S.W., found the ζ *Cassiopeids* ($4^{\circ}+52^{\circ}$) very active. Mr. Bridger, of Farnborough, saw the δ *Cassiopeids* ($17\frac{1}{2}^{\circ}+58^{\circ}$), as did also Mr. A. King, of Leicester ($21^{\circ}+60^{\circ}$). At Bristol the best shower was from *Draco* at $277^{\circ}+70^{\circ}$. The position of the main radiant point of the *Perseids*, as observed during the first half of August, showed the usual motion to the eastward, but there were comparatively few observations before August 9. On the following six nights the mean places of the radiant, from

observations by Antoniadi, Besley, Bridger, King, and Denning, were as follows :—

		α	δ		
August	9	...	$43^{\circ}3' + 56^{\circ}5'$	...	3 radiant
"	10	...	$44^{\circ}4' + 56^{\circ}9'$	...	5 "
"	11	...	$45^{\circ}5' + 56^{\circ}9'$	...	5 "
"	12	...	$46^{\circ}9' + 57^{\circ}2'$	...	5 "
"	13	...	$48^{\circ}5' + 56^{\circ}5'$	...	2 "
"	14	...	$50^{\circ}3' + 57^{\circ}2'$	...	3 "

At Bristol on August 16 seven *Perseids* indicated the radiant at $53^{\circ} + 57^{\circ}$. The displacement in the position from night to night is therefore shown in a very striking manner. From observations of this shower in and since 1893 our knowledge has been rendered pretty complete ; but the display requires attentive watching in its earlier stages during the last half of July. A considerable number of *Perseids* were observed at more than one station, and several of the brighter examples are included in the table of real paths.

The Leonids.—Preparations were made everywhere to witness and suitably record the display of *Leonids* at the middle of November. The weather was partly clear at some places, but the shower failed to return in exceptional strength. The number of meteors seen did not exceed those counted in the few previous years at the same epoch, and the display fell below the average richness of the August *Perseids*. It was intended that photography should play an important part in accurately recording the flights of bright meteors near the radiant, but the attempts appear to have signally failed. At a few stations an isolated track was found on the plates, but the shower proved altogether too poor to give success either to the photographic or visual method. A vast number of reports have been received from England and foreign places, and they are in fair accordance. The maximum occurred on November 14, 17^h to 18^h G.M.T., when, however, the horary rate of *Leonids* visible for one observer scarcely exceeded twenty-five. There was a decided falling-off on the night following November 15 as compared with the number seen on the preceding night. From the rate of apparition given by several observers it would appear that *Leonids* were increasing when the morning twilight of November 15 terminated observations ; but the descriptions from longitudes far west of Greenwich do not support the inference that a strong shower occurred after sunrise in England. In America the event was awaited with the same intense interest as in this country, but observations proved similarly disappointing, for the display was one of third-rate character. The maximum of the shower, such as it was, occurred both in 1898 and 1899 on the morning of November 15, though computations had indicated it about a day later. It

seems highly probable that 1899 was really too early to expect a visible return of the main swarm. There were brilliant displays in 1866, 1867, and 1868, and a recurrence of the first of these would not be due in 1899 November by several months if the period is about 33·3 years. The middle of the swarm probably came in 1867, and our prospects for 1900 and 1901 are certainly more inviting than they were in 1899, unless indeed the major planets have disturbed the orbit in sufficient degree to enable the richest part of the group to escape contact with the Earth.

The Andromedids.—Perhaps the most interesting meteoric event of the year was the occurrence of a well-marked, if not very brilliant, shower of the meteors associated with Biela's comet. Near Vienna Dr. S. Oppenheim and several other observers watched the display on November 23, and between 4^h 56^m and 8^h 36^m G.M.T. counted sixty-five meteors. On November 24, between 7^h 56^m and 9^h 26^m, they counted 240 meteors. The maximum was at about 7^h, when meteors were falling at the rate of about ninety per hour. On November 23, 8^h 21^m G.M.T., a large fire-ball was seen passing from 100° + 10° to 90° + 0°. Professor C. A. Young, at Princeton, N.J., says that on November 24, for a short time about 15^h G.M.T., the number of meteors observable by a single person was two or three a minute. After 16^h, only three meteors appeared in fifteen minutes. The place of the radiant was estimated at 23° + 42½°. "It was obviously not a point, but an area 2° or 3° in diameter." At Northfield, Minn., Professor H. C. Wilson and several other observers saw a considerable number of meteors on November 24. A systematic watch was not commenced until about 16¼^h G.M.T., when in the first five minutes one observer saw ten *Andromedids*. The shower was nearly over an hour later. The place of the radiant was one-third of the way on a line from γ to ϕ *Andromedæ*. At Boston, Mass., Mr. R. M. Dole watched from 11^h 40^m to 14^h 42^m G.M.T., and counted sixty-four *Andromedids*, eleven *Taurids*, and other meteors. In a diagram in *Popular Astronomy*, 1900 January, he puts the radiant close to β *Andromedæ*. Dr. Villiger at München, Germany, observed a few meteors of the shower on November 23 and 24, and placed the radiant at 1^h 17^m·5 + 37°. In England the weather was not very favourable, but at Norwich Mr. Willis counted sixty-two meteors between 10^h and 11^h 25^m, and of these fifty-two were probably from *Andromeda*, but he does not give the place of the radiant (*Nature*, December 7). The Earth appears to have passed through the extreme rear end of the shower at its recent appearance, and a brilliant return may be expected on 1905 November 17 or 18, when we are likely to encounter a region of the swarm much nearer the remains of the parent comet.

Professor Herschel, in a series of watches extending over twelve hours on November 6-16, recorded five *Leonid* and sixty-nine non-*Leonid* meteors, and made a careful investigation (*Nature*, 1900 January 4) of the contemporary showers of the

epoch. He found radiant at $52^{\circ}+8^{\circ}$, $68^{\circ}+17^{\circ}$, $121^{\circ}-1^{\circ}$, $134^{\circ}+67^{\circ}$, and $143+29$.

The following is a list of the real paths of bright meteors observed in England during the past year :—

Date.	G.M.T.		Bright- ness.	Height at First. miles	Height at End. miles	Length of Path. miles	Velocity per Sec. miles	Radiant Point.	Observers.
1899. March	h	m							
	1	7 0	4 × ♀	73	28	53	21	119 + 31	3
	1	8 49	> ♀	58	22	39	10	119 + 33	3
April	4	7 59	2 × ♀	60	52	160	slow	202 — 10	3
June	2	8 47	♀	61	51	170	slow	250 — 23	4
Aug.	10	10 14	♀	76	40	54	v. swift	41 + 57	4
	10	10 54	4	97	51	79	v. swift	45 + 58	4
	24	8 11	)	77	27	118	17	345 + 14	49
	27	10 13	> ♀	68	47	143	25	191 + 32	6
Sept.	2	12 5	3 × ♀	86	60	28	swift	46 + 42	2
	4	8 13	4 — ♀	67	21	52	34	311 + 79	2
	8	8 21	> ♀	71	26	114	20	347 + 3	2
Oct.	2	8 24	♀	67	45	88	13	284 — 17	3
Nov.	14	17 40	♀	71	42	46	swift	193 + 27	7
	15	16 48	> ♀	83	50	43	swift	150 + 20	4
	15	16 50	> ♀	82	45	49	swift	151 + 21	3
	19	8 5½	4	85	42	68	23	60 + 28	2

W. F. D.

Solar Activity in 1899.

With the solitary exception of the numbers of the prominences, every class of solar phenomenon showed a diminished activity in 1899. Mr. Evershed reports that the mean number of prominences which he observed was almost precisely the same as in 1898, though their average size and extent were perceptibly diminished. Their distribution in solar latitude remained much the same, the southern hemisphere having a slight preponderance over the northern. The mean daily numbers of prominences seen in the two hemispheres are as follows :—

				1898	1899
North	...	...	...	3'32	3'27
South	...	...	...	3'65	3'73
Total	...	...	...	6'97	7'00

In each hemisphere there has been a well-defined limit in latitude, beyond which in the polar regions prominences have been rare and very small. This limit has been approximately :—

			1898	1899
North latitude	...	...	$+56^{\circ}$	$+54^{\circ}$
South latitude	...	...	-53°	-53°

D D

Metallic prominences have been most infrequent ; only five prominences having been seen in 1899, which reversed the lines of sodium and magnesium ; and of these only one was north of the equator.

One large prominence of the eruptive class was observed on June 2 near the solar equator.

The change as to spots and faculae has been most striking. The mean daily spotted area for 1899, to judge from the results as yet to hand, will not probably exceed 100 millionths of the visible hemisphere, as compared with 375 for 1898. M. Guillaume gives for the total spotted area for the first nine months of 1899 2980 units, as compared with 7951 for the previous year ; a falling off of nearly 63 per cent. The same observer records almost as great a diminution of the faculae ; the area for the year just past being only 52 per cent. of that for the year which preceded it. The days when the Sun showed no spots have more than doubled in number, chiefly owing to a striking sub-minimum extending from July 17 to October 23, and there has been a complete absence of any really remarkable outburst ; the last fortnight in March having shown the most noteworthy spot group of the year, and this at its greatest development only attained an area of 620 millionths.

E. W. M.

Total Solar Eclipses.

No total solar eclipse took place during last year.

1898 January 22.

A few accounts of work done at this eclipse have been published, but the majority of observers have not yet completed the final reductions and discussions of their observations, so that we are not yet in a position to give any detailed statement of the results arrived at.

1900 May 28.

The preparations for this eclipse are well forward. The weather conditions in Portugal, Spain, and Africa appear to be favourable, though it is unfortunately not probable that the very exceptional clearness of atmosphere that was found in India in 1898 will be repeated. It is understood that the American astronomers are preparing for work in their continent with their usual energy, and should totality remain unobscured at both ends of the line, the comparison of the large scale corona photographs will be of considerable interest.

E. H. H.

Astronomical Papers of the American Ephemeris.

During the past year Professor Newcomb has published tables of the heliocentric places of *Mars*, *Uranus*, and *Neptune*, thus completing his tables of the major planets. These conclude a

large and important section of the work which Professor Newcomb proposed to himself on his appointment as Superintendent of the American Ephemeris more than twenty years ago : "The ultimate problem in view was the construction of new theories and tables of the celestial motions generally, based on consistent values of the fundamental constants, which should themselves be determined from all the available data of observation."

The tables of *Mars* are similar to those of the Sun, *Mercury*, and *Venus*, of which an account is given in the Council Report for 1896. The method of formation of the tables of these planets is described in Professor Newcomb's *Elements of the Four Inner Planets and the Fundamental Constants of Astronomy*. The publication of the tables of *Mars* was delayed somewhat by apparent discordances between theory and observation ; the most important discrepancy was traced to the fact having been overlooked that an inequality of the second order due to the product of the masses of the Earth and *Jupiter* is not contained in Leverrier's Tables. Professor Newcomb remarks that there are two questions which require further investigation : (1) the excess of the observed over the theoretical motion of the perihelion amounts to $6'' \pm 2''$ per century ; (2) the determination of the mass of *Venus* by means of the term of long period (about thirty-three years, with amplitude $6'' \cdot 5$) in the motion of *Mars*.

The theory of the motion of *Uranus* and *Neptune* on which these tables are based is not yet published. The observations employed are those of the two planets made at Cambridge, Greenwich, Paris, and Washington, since the dates of their discovery down to the present time, along with Lalande's observations of *Neptune* in 1795. The mass of *Neptune* was derived from the measures of the satellite, and from the observations of *Uranus* from 1781 to 1896. The elements used in constructing the tables are given as affected by the long inequality of 4220 years, arising from the mean motion of *Uranus* being nearly twice that of *Neptune*. The form of the tables is slightly different from that used in the tables of the four inner planets, and, as in the case of the latter, is remarkably convenient for the computation of ephemerides. The residuals in longitude and parallax of *Neptune* are tabulated, but are not found to be of a systematic character such as would arise from the action of an unknown body.

The completion of the planetary tables affords a convenient opportunity for recapitulating the important series of papers which have up to the present time emanated from the office of the American Ephemeris, and most of which have been noticed in detail in previous reports of the Council (vols. xlii. xlv. xlv. xlvii. lvi. lviii. lix.). They may be nearly all included in the four following groups :—

1. Catalogues of fundamental stars, published in 1872 and 1899 ; determinations of the velocity of light and of the constant of aberration (in this Professor Newcomb was

assisted by Professor Michelson) ; a discussion of Greenwich and Washington North Polar distances, and a determination of the constant of nutation from them ; the constant of precession.

2. Discussions of the Moon and of Transits of *Mercury*, by Professor Newcomb ; the discussion of the Greenwich Planetary Observations from 1762-1830, by Professor Safford.
3. Four papers on the Lunar Theory, two by Professor Newcomb ; a transformation of Hansen's Theory compared with Delaunay's ; the action of the planets on the Moon ; and two by Dr. Hill on the lunar inequalities due to *Jupiter*, and lunar inequalities depending on the figure of the Earth.
4. A series of papers on the theory of the four inner planets by Professor Newcomb, forming the basis of his tables of their motions ; the theory of *Jupiter* and *Saturn*, by Dr. Hill, and the tables of their motions based on it ; the tables of *Uranus* and *Neptune* by Professor Newcomb, just published.

The enumeration of these papers, though incomplete, shows what a debt astronomy owes to the office of the American Ephemeris, and especially to Professor Newcomb and Dr. Hill.

F. W. D.

Variation of Latitude.

Some years ago the International Geodetic Association determined to carry out an elaborate scheme for the systematic observation of those variations of latitude to which Küstner first drew effective attention. It was considered that the Talcott method would give the most satisfactory results, and that method has accordingly been adopted. The same form of zenith telescope is to be used at all the stations, and the instruments have all been carefully tested at Potsdam. An exact programme for observation has also been arranged at the Bureau of the Association.

In order to avoid possible errors in the determination of the declinations of stars, and especially errors in the estimated proper motions, it was resolved that the same stars should be observed at all the stations. This involved the choice of places lying in the same parallel of latitude. After careful consideration of meteorological and geological data, Dr. Helmert fixed on the parallel of $39^{\circ} 8' \text{ N.}$ as meeting all the requirements of the case.

The coordinates which express the motion of the pole would be determinable from observations taken at three stations, properly distributed as to longitude, but for the sake of greater precision six stations have been chosen. They are as follows :—

1. Torre di San Vittorio, Carloforte, in the island of San Pietro, lying close to the coast of the island of Sardinia. The observatory is in latitude $39^{\circ} 8' 12''$, and in about 9° of east longitude.

2. A place nine kilometres north of Charjui, on the Amu Daria, in latitude $39^{\circ} 8' 10''$, and east longitude $63\frac{1}{2}^{\circ}$.

3. Mizusawa, in the valley of Kitakami, Japan. The observatory is in latitude $39^{\circ} 8' 0''$, and in east longitude about 141° .

4. Ukiah, California, in latitude $39^{\circ} 8' 0''$, and west longitude about 123° .

5. The permanent observatory at Cincinnati, in latitude $39^{\circ} 8' 19''$, and west longitude $84\frac{1}{2}^{\circ}$.

6. Gaithersburg, Maryland, a station on the Baltimore and Ohio Railroad, about 30 miles north-west of Washington. The latitude is $39^{\circ} 8' 10''$, and west longitude 77° .

Invitations to cooperate will also be addressed to a number of other observatories.

A full account of the whole project is given in the *Comptes Rendus* of the Stuttgart Conference of 1898.

The work was begun in the autumn, and the first books of results have already been received at Potsdam from Carloforte, Charjui, and Cincinnati.

It is intended that the observations shall be continued for at least five years, and the results will be reduced at Potsdam.

G. H. D.

The Variations of Gravity at the Earth's Surface.

The International Geodetic Association has continued its systematic researches as to the local deflections of the vertical which are found to occur at various places. A large mass of material now awaits reduction at Potsdam, and it is expected that valuable results will be obtained as to the value of gravity and as to the Earth's figure.

Mr. Richard Threlfall and Mr. J. A. Pollock have devised and experimented with a new form of gravity balance.* In this instrument the authors have availed themselves of the remarkable elastic properties of quartz fibres. The construction and design of the instrument have involved a high degree of experimental skill, and the inventors are to be congratulated on the success which has attended their difficult enterprise. It seems probable that the comparative values of gravity at various places may now be obtained with a facility which was previously unattainable. The results may perhaps be not quite so accurate as those obtained by the best swinging of pendulums—although there is every reason to believe that the instrument will reap the benefit of further experience—but

* *Phil. Trans. A.* 1899, paper 245.

observations which, by the older methods, would require days or even weeks to accumulate will now be obtained in a few hours. The defect of the instrument resides in the fact that it depends on the life of an individual fibre of quartz; but the extraordinary toughness and vitality of Threlfall's fibres seem to show that this is a far less serious defect than might have been anticipated.

G. H. D.

The Measurements of Base Lines and Standards of Length.

Geodesists* continue to be more and more impressed by the advantages to be gained by M. Jäderin's method of measuring base lines. In this method the base is measured by unrolling a metallic tape of considerable length; and the gain in rapidity is so great that henceforth a number of subordinate bases will be laid out, where formerly reliance would have been placed solely on a single long base line for a large tract of country.

A new alloy, consisting of 36 per cent. of nickel and 64 per cent. of steel, has been found to possess the remarkable property that its coefficient of expansion only amounts to one-fiftieth of that of steel. This alloy is now being used for the construction of M. Jäderin's apparatus, and also for standards of length by the International Committee of Weights and Measures at Breteuil. Great advantages are anticipated from this remarkable discovery.

G. H. D.

The Astrographic Chart and Catalogue.

There has been no recent number of the bulletin of the Permanent Committee, and no information has been obtained as to the progress made during the year in the measurement of the photographs in other than the British observatories. The progress made at Greenwich, Oxford, the Cape, Sydney and Melbourne, is referred to in the reports to the Council from these observatories.

During the year two important publications have appeared, viz., the first volume of the Potsdam measures of Catalogue Plates, and the first issue of twenty enlargements of the Paris Chart Plates. It is most satisfactory to know that a beginning has at last been made in actual publication, and we believe that the work of English observatories will also soon be in print. The Paris charts are most beautifully done; each plate is enlarged to double the size (linear), or four times the area, as a heliogravure on a sheet of thick paper 22 in. $\times$ 17 in. The star images are shown as clear little dots in groups of three, each dot representing an exposure of thirty minutes, and the French are to be congratulated on the production of a piece of work of a kind in

* See *Comptes Rendus* of Internat. Geod. Conf. at Stuttgart, pp. 27 and 277.

which they always excel. But attention should be drawn to the dimensions that the whole chart will have on this scale. Twenty maps are over a third of an inch thick, and weigh $3\frac{1}{2}$ lbs. The 22,000 maps of the whole chart will thus form a pile of paper 22 in. by 17 in. in section, and thirty feet high, weighing nearly two tons, and the total expense will be enormous. The cost of each sheet must be at least two shillings, which means £2,200 for the whole. It almost seems as though the smaller observatories would be crowded out after all. These sheets are of course being generously presented by the French Government; but if the chart is to be homogeneous, each observatory must present similar copies of its own zones in return, so that the sum above quoted must be spent on behalf of each observatory, in one form or another, for the maps alone.

Nor is the Potsdam volume much more reassuring in this respect. It contains the measures of fifty-seven plates; and if all the measures are printed on the same scale, there will be nearly 400 such volumes, occupying just four times the space of the Greenwich volumes for the last half-century. Are not the large observatories setting too high a standard? It seems more than probable that the smaller observatories must be content with a much more modest chart, such as Professor Pickering is continually constructing at Harvard; and as regards the publication of the measures, we must print them less like an *édition de luxe*, and more like the Greenwich results already in proof, which contain three or four times as many stars in a page as the Potsdam volume.

As regards the contents of this volume, in the Introduction Dr. Scheiner explains his method of measurement by means of two micrometer screws at right angles. He finds the work very laborious; two people, a measurer and an assistant, measure thirty stars per hour, and there is still some work for a computer before the printed rectangular coordinates are deduced. It is perhaps a fair estimate to take ten stars as the result of *one* person's labour per hour. Twenty years seems about the time which it is proposed to spend on the measurement alone at Potsdam. The plates are measured in one position only, and the results are thus affected with personal equations depending on magnitude to the extent of $0''.6$ in some cases, though the accidental error of bisection has been certainly made small. These personalities have been determined, but apparently not applied. And Dr. Scheiner does not undertake to determine the plate-constants. He considers that this will be best done when the whole work is repeated in 100 years' time; his argument is that the labour of finding both sets of plate-constants together will be less than twice that of finding one set separately; and hence it would be false economy to do our half of the work now (*see* Introduction, p. xxxvi). The principles stated on pp. xxii and xl of the Introduction are not quite accurate; for instance, the plate is only corrected on p. xl for orientation, when refrac-

tion and aberration might just as readily have been included, as has been shown in numerous papers in the *Monthly Notices* during the last six years.

Dr. Scheiner has also partially discussed, both in this Introduction and in various papers in the *Astronomische Nachrichten*, the distribution of stars of different magnitudes, especially the point established by Kapteyn that the stars near the Milky Way are brighter photographically than visually; but he does not seem to have added anything to Kapteyn's discussion; indeed, as Kapteyn has himself pointed out, we shall not gain much by repeating the sort of work which he has done so fully and admirably in the *Cape Durchmusterung*; what is wanted is a special investigation such as is being undertaken at the Cape.

H. H. T.

Star Catalogues.

Catalogue of Fundamental Stars for the Epochs 1875 and 1900 reduced to an Absolute System.—This catalogue, undertaken by Professor Newcomb at the request of the Paris Conference of May 1896, is published in vol. viii. part ii. of the *Astronomical Papers*, prepared for the use of the American Ephemeris and Nautical Almanac. A list is given of 1597 stars, which occur in various ephemerides and fundamental catalogues, but insufficiency of material, especially in the case of southern stars, caused Professor Newcomb to reduce the number of stars in his catalogue to 1260. With the exception of the close polars, the stars are generally brighter than the sixth magnitude, and, as far as practicable, are distributed so that stars are given at intervals of from fifteen to twenty minutes for each zone of 10° near the equator, and at intervals of twenty to twenty-eight in higher zones.

The material at Professor Newcomb's disposal may be roughly summarised as Auwers' Bradley, the standard catalogues of Struve and Argelander, and various catalogues from 1830 to the present date of the Cape, Greenwich, Melbourne, Poulkova, and Washington Observatories. The difficulties in the deduction of a standard catalogue from these consist mainly in the determination of the systematic corrections, and to a certain extent in the weighting of the different catalogues, especially of Auwers' Bradley.

In the Right Ascensions Professor Newcomb adopts the equinox of "Newcomb's Catalogue of 1098 Clock and Zodiacal Stars." This differs from that adopted in the Fundamental Catalogue of the *A.G.C.* by $+^s.019 - ^s.100 T$, where T is measured in decimals of a century from 1850. Terms of the form $a \cos a + b \sin a$ are applied to correct the periodic error in Right Ascension which crept into the adopted Right Ascensions used at Greenwich between 1830-1840, and which was reproduced by many observatories using Greenwich clock stars, and which has

only been eliminated by successive revisions. For the error in Right Ascension depending on declination, use has been made of Dr. Auwers' tables giving the correction to reduce the different standard catalogues to the system of the *A.G.C.* The differences for each catalogue between the correction for each zone of 5° and the mean correction applicable near the equator are treated as giving corrections of the form $x+yT$ to the system of the *A.G.C.*, for each zone of 5° . The deduced corrections are added to the mean correction $+^s.019-^s.100T$ applicable to the *A.G.C.* stars near the equator, and by applying these corrections to the *A.G.C.* to Auwers' Tables, the adopted corrections to the Right Ascension of the various catalogues are derived.

For the declinations Professor Boss's Catalogue has been used as furnishing a provisional or intermediary system. Professor Newcomb deduces $+0''.09+0''.38T$ (as before measuring T in decimals of a century from 1850) as a correction applicable to Boss's declination in the region of the equator. This correction is derived from observations of the planets, and is an expression of the fact that their orbits are in planes through the Sun's centre. This result, deduced from planetary observations, though supported to some extent by the observed declinations of stars at Greenwich and Poulkova, cannot be said to be well determined. It is, however, adopted as the best obtainable at the present time. Using the tables given by Professor Boss for reducing to his system, equatorial corrections to Newcomb's system are deduced; the correction is usually assumed to be zero at the pole, and to increase uniformly to the equator. In this way the corrections are obtained to Boss's system from the standard catalogues, modified so that the mean equatorial correction will be $+0''.09+0''.38T$. These are solved as giving corrections of the form $x+yT$ to Boss's declinations for every 5° of declination, and the corrections of the standard catalogues to Newcomb's system derived.

No corrections having the Right Ascension as argument are applied to the declinations.

Tables are given of the systematic corrections to reduce the different catalogues to Professor Newcomb's system, and attention may be drawn to the remark that "the practice of applying systematic corrections has of late years been carried too far. Corrections for errors proceeding from causes not known with numerical exactness, but yet plausible, are unobjectionable. But correction for seemingly systematic errors, which cannot be plausibly traced to a known cause, should be regarded with suspicion."

Auwers' Bradley is considered at some length. It is found to require an equinox correction of $-0^s.079$; no periodic correction to the Right Ascension is required, and a correction depending on the declination, whose maximum value is about $-0^s.030$, is deduced.

For the declinations a correction depending on Right Ascension is deduced ; but Professor Newcomb states that his work on the precessional constant showed that these corrections would have been better omitted. The correction depending on declination resolves itself into the question whether the corrections to the readings of Bradley's quadrant deduced by Dr. Auwers should be retained or not. Professor Newcomb uses them for stars north of 47° of dec., but not for stars south of this limit, pending the publication of Dr. Auwers' discussion.

The correction of Right Ascensions for personality depending on magnitude is discussed, but no corrections are applied except in the case of Pulkova, 1845 and 1865.

Professor Newcomb applies no corrections for variation of latitude, as these corrections can only be applied as corrections for each day in the reductions of observations, and not to a catalogue. In an appendix to the catalogue formulæ and data are given for the reduction of mean places and proper motions of stars from one epoch to another.

Cape General Catalogue of Stars for 1890.—This catalogue of 3007 stars is derived from observations made in the years 1885–1895. The stars observed are stars brighter than the fourth magnitude, fundamental stars, southern circumpolars, and stars required in the determination of latitude and longitude in connection with the geodetic survey. The Right Ascensions of the clock stars are derived from the *Berliner Jahrbuch*, and are those of Auwers' *Fundamental Catalog*.

The correction of the Right Ascensions for personality depending on magnitude is considered, and $-0^s.014$ ($M-4.0$) is given as a mean correction, which may be applied to the Right Ascensions of the catalogue. It is stated that in future fundamental work at the Cape the magnitude equation will be frequently determined for each observer, and the corresponding corrections applied to his observations.

For the declinations two results are given ; in both a correction is applied for flexure derived from observations on the collimator ; in the first or provisional values the refractions of the *Tabulæ Regiomontane* are used ; in the final determination these are diminished in the ratio $1-0.00218$. But the most interesting feature of the reduction is that the correction for variation of latitude has been applied to the observations.

In an appendix to the catalogue are given comparisons of the catalogue with the Greenwich Five-year Catalogue and with the *Berliner Jahrbuch*, and also with the Cape Catalogues for 1880 and 1885, the Greenwich Ten-year Catalogue for 1880, the Radcliffe Catalogue for 1890, and the Melbourne Catalogue for 1880. The results of these comparisons are summarised in the Introduction in the form of tables of systematic differences between the Cape Catalogue and these various catalogues for each hour of Right Ascension and for each 5° of declination.

In a second appendix the meridian observations of *Sirius*,

Procyon, α and β *Centauri* from 1886 to 1895 are collected, reduced without proper motion to the epoch 1890.0.

In a third appendix the positions and proper motions of twenty-four southern circumpolar stars used for azimuth determination are determined from Cape observations and those at Melbourne and Cordoba. A Catalogue of the mean Right Ascensions and Declinations of these stars is given for every fifth year from 1875 to 1920.

Attention may be drawn to a remark of Dr. Gill's, "that the existing transit-circle is now exclusively employed in zone observations, and a new transit-circle is under construction for future fundamental work. The present Catalogue is thus probably the last of its class that will emanate from the Cape Observatory as the result of work with a non-reversible instrument."

The Catalogue of the Astronomische Gesellschaft.—Leipzig Zones.—Zone $+5^{\circ}$ to $+10^{\circ}$ has been published this year, and Zones 10° to 15° are in the press. The former contains 11,875 stars, and the latter will contain 9547 stars. The northern half of the *Gesellschaft* Catalogue from -2° to $+80^{\circ}$ decl. is thus nearing completion; the zones still unpublished are those of Lund and Leiden, extending from 30° to 40° N. decl., and the Dorpat Zone from 70° to 75° . The Leipzig Zone from $4^{\circ}42'$ to $10^{\circ}0'$ N. decl. was observed with a Pistor and Martin's circle by Drs. Bruns and Peter in the years 1868-72 and 1883-93. The majority of the stars are observed twice, but a considerable proportion of the stars are observed oftener. A comparison with the Greenwich new Ten-year Catalogue, 1890, shows a difference of $^s.05$ in the Right Ascensions and $-0''.3$ in the Declinations. There appears to be no systematic difference either in R.A. or Decl., depending on the Right Ascension. The mean discordance between the two catalogues from comparisons of the 160 stars common to them is $\pm^s.039$ in R.A., and $\pm 0''.49$ in Decl.

F. W. D.

Double Stars.

As in previous reports the work is arranged under the two heads, "Observation" and "Calculation."

Observation.—*Mem. R.A.S. Vol. liii.* contains measures of 161 pairs made with an 8-inch Cooke refractor in the years 1893-96 by Mr. W. Coleman; also of 98 pairs made by Mr. Maw with an 8-inch formerly used by Dawes. This set brings Mr. Maw's measures up to 1808.

Monthly Notices R.A.S. 1899 April.—Measures of 73 pairs made at Shanghai by Mr. J. L. Scott with a 5-inch refractor; also the mean results of micrometric measures of 420 pairs made with the 28-inch Greenwich refractor during the years 1896, 1897, 1898.

Astronomical Journal.—No. 429 contains measures of 83 close pairs made at Lick by R. G. Aitken. (This set was unfortunately omitted in the last Report.) No. 462.—Measures of *Procyon* by E. E. Barnard. No. 468.—Measures of ζ *Herculis* by T. Lewis (1894-99).

Astronomische Nachrichten.—No. 3537 contains W. Schur's measures of 70 *Ophiuchi* in 1898, No. 3558 a catalogue of 132 new doubles (Hough 491-622), and a good set of measures of 255 other pairs by G. W. Hough with the 18½-inch Dearborn refractor. No. 3563.—M. Solà gives his third series of measures (50 pairs). Nos. 3584-5 contain a fine series of measures of some 400 pairs by R. G. Aitken with the 36-inch Lick refractor (includes measures of *Sirius* and *Procyon*); the same number contains measures of *Sirius* by Professor W. Hussey.

Astronomical Society of the Pacific.—No. 66.—Professor Aitken has some notes and measures of β *Orionis*, ϵ *Hydræ*, 48 *Cassiopeie*, *Procyon*, and H 529. In the same number is a new close pair by Perrine. No. 68 contains measures of *Sirius* by R. G. Aitken, and three new close pairs. No. 69.—Five new pairs by R. G. Aitken.

Popular Astronomy.—No. 63.—Professor W. Hussey gives four new pairs.

Calculation.—*Ast. Nach.* 3588.—Orbit of *Sirius* by H. Zwiers, who, using observations down to 1899.3, obtains a period of 48.84 years. No. 3546.—Note on systematic error in the Poulkova double star measures by V. Ehrenfeucht. No. 3593.—Parallax of Σ 1516 by Ö. Bergstrand.

Astron. Journal.—No. 460.—Orbit of ζ *Herculis* by Eric Doolittle. Period 35.55 years. There is a further note by the same author in No. 466, where a comparison is made between observed and computed places. In 461 Professor F. R. Moulton has a paper on "The Limits of Temporary Stability of Satellite Motion," with a special application to the system 70 *Ophiuchi*.

Popular Astronomy.—No. 61.—Note on β 107 by S. W. Burnham. No. 66.—Rough orbit of Dembowski 15 by Mr. Evans.

The Observatory.—No. 277.—Motion of Σ 1263 by T. Lewis. No. 285.—Parallax of Σ 1516. No. 286.—Note by T. Lewis on the system 7 *Tauri* (Σ 412). The close pair is binary, the third star apparently being unconnected with the system.

Reference Catalogue of Southern Double Stars.—This catalogue, by Mr. R. T. A. Innes, is published as "Annals of the Royal Observatory, Cape of Good Hope," vol. ii. part ii., and is a most valuable descriptive catalogue containing over 2000 stars arranged in order of R.A., and each star is accompanied by a sufficient number of measures (where possible) to enable an observer to see at once those pairs which want measuring, and which lie within the limits of his instrumental means. It also contains a most complete list of works and papers on double stars. Such a catalogue as this had become an urgent necessity. T. L.

Longitude Determination.

The only recent publication which comes under this heading is that of the details of the arc Leyden—Greenwich, measured in the year 1880 by the brothers H. G. and E. F. van de Sande Bakhuyzen, which appear in volume vii. of the *Leyden Annals*. The provisional result was given in the report of the International Geodetic Association for 1883, and the definitive result in a subsequent report of the same body, so that there is not any information which is actually new, but it may be of interest to note some details.

At Leyden the meridian circle of the Observatory was used for determination of time. At Greenwich a transit *à lunette brisée* of aperture 67·8 mm. and focal length 861 mm., on an iron stand, was mounted in the south ground at Greenwich, on the same stone base that Professor Oppolzer had used in 1876. This instrument was easily reversed in its bearings, and it was so reversed several times during an evening's work. The meridian circle at Leyden was reversed once only during each of the periods into which the work was divided.

The observers interchanged stations once. This interchange is sufficient to determine, and hence eliminate the relative personal equation of the observers ; but as there may be a personality due to the instruments used, some months after the Greenwich observations were completed the smaller instrument was set up at Leyden, and the observers repeated the operations exactly, so as to determine the small difference of longitude between the instruments which was known by direct measurement. The relative personal equation deduced from these observations was H.B.—E.B.=—0^s·293. From the previous observations it had been—0^s·258. Comparison of the determined longitude with the linear distance showed a difference of clock-error due to the instruments of 0^s·012 and some account of this being taken in the discussion of results, the difference of longitude arrived at between the meridians of the Greenwich transit circle and that of Leyden is 17^m 56^s·10.

The most unsatisfactory detail of the operations appears to be the telegraph signals. Although care was taken to equalise the strength of currents in sending and receiving signals, it is possible that the times of transmission, which were sometimes large, were not always the same in opposite directions, but Professor Bakhuyzen thinks that the error of the result due to this cause cannot be more than ^s·01 or ^s·02.

It is worth remarking that a few years later the difference of longitude between Leyden and Paris was determined telegraphically, with result 8^m 35^s·213 ; the combination of these results gives for the longitude of Paris 9^m 20^s·89 East of Greenwich.

H. P. H.

Stellar Spectroscopy in 1899.

Spectrum of Nebulæ.—From a photograph obtained with an exposure of $7\frac{1}{2}$ hours, at Potsdam, of the spectrum of the *Andromeda* nebula Professor Scheiner (*Astroph. Journ.* ix. 149) infers that the nucleus is composed of stars that belong in the main to the solar class. Professor Scheiner calls attention, in a suggestive manner, to a point which deserves systematic investigation, viz. the difference between the spectra of ring nebulæ and spiral nebulæ.

Professor Keeler has made reference, in a paper on the ring nebula in *Lyra* (*Astroph. Journ.* x. 200), to the preparation of apparatus suitable for this and allied researches, and results of great importance may be expected.

New Star in Sagittarius.—A new star was discovered by Mrs. Fleming, of the Harvard College Observatory, by the peculiarities of its spectrum as photographed in March 1898. It was then a star of the fifth magnitude, but at the time of its detection—viz. in March 1899—it was found to be of the tenth magnitude. Eighty-seven plates of the region were examined, and the search only showed that it was too faint to be photographed between the years 1888 and 1897. Professor E. C. Pickering (*A. N.* 149, 57) states that the *Nova* is invisible on the last plate of the region taken in 1897, though stars of the fifteenth magnitude are to be seen on the plate. The star probably appeared either at the end of 1897 or early in 1898. It is of great interest, both on account of its having at its first appearance peculiarities in its spectrum—which Professor Pickering regards as possibly affording a general method of distinguishing between a *Nova* and a variable—and also on account of the fact that it appears to have passed through changes similar to those presented by *Nova Cygni*, *Nova Aurigæ*, and *Nova Normæ*. Furthermore it makes its appearance near the central line of the Milky Way, a fact which must have significance when it is considered, as Professor Pickering points out, that fourteen out of the fifteen new stars which have been observed during the last 400 years have been situated close to that line.

Professor Campbell's visual observations (*Astroph. Journ.* ix. 308) in April 1899 show that the spectrum was at that time similar to that of *Nova Aurigæ* in August 1892, and the resemblance to the planetary nebular spectrum is no less striking.

Phenomena of Spectrum of New Stars.—A striking feature in the spectrum of *Nova Aurigæ* (1892) at its first outburst was the occurrence of pairs of lines, a bright line and a dark line side by side, the dark line being more refrangible. The same feature was visible in *Nova Cygni* (1876), in *Nova Normæ* (1893), and in *Nova Sagittarii* (1898), and it is now regarded as a peculiarity of new stars. Belopolsky also announces (*Ast. Nach.* 151, 37,

and *Astroph. Journ.* x. 319) that the same feature is still seen in Janson's *Nova* of 1600, now known as *P Cygni*; and it is connected not only with the helium and hydrogen lines, as has long been recognised, but also with lines which seem to be attributable to nitrogen. In all of these cases the bright lines are displaced towards the red. The researches of Humphreys and Mohler show that such displacement is produced by increase of pressure in the incandescent vapour. Herr Wilsing, in trying to extend the work of these experimenters, has investigated the spectra of spark discharges below the surface of liquids (*Sitz. ber. Berlin. Akad.* 1899 May, and *Astroph. Journ.* x. 113). He finds in many of the spectra examined there are pairs of lines, consisting of a bright and a dark line, the bright line being displaced towards the red, whilst the displacement of the dark component is seldom appreciable. In the case of copper and cadmium the shifts of the bright lines amount to 4 or 5 tenth-metres, and in the zinc the bright line 4722 was shifted through 14 tenth-metres. In new stars displacements of the bright line through 8 or 10 tenth-metres are observed, and this is accompanied by a shift of the dark lines towards the violet. Herr Wilsing finds little evidence of the shifting of dark lines in the case of metallic spectra, but has succeeded in getting striking results with hydrogen (*Sitz. ber. Berlin. Akad.* 1899 July, and *Astroph. Journ.* x. 269). Much remains to be done in the subject, but it is clear that Herr Wilsing has entered upon an important research, not only in the study of the broadening, both symmetrical and unsymmetrical, of metallic lines, but also in particular with reference to the spectroscopic behaviour of hydrogen. He deals with the application of his observations to the case of new stars, in *Ast. Nach.* 151, 33, No. 3603.

Chemistry of Stars.—Mr. McClean's identification of oxygen in helium stars, e.g. β *Crucis*, has been confirmed by Dr. Gill at the Cape of Good Hope by careful comparison of wave-lengths of the stellar lines with oxygen and other comparison spectra (*Proc. R.S.* lxx. 196, and *Astroph. Journ.* x. 272). This is, we believe, the first piece of research carried out with the splendid spectroscopic installation presented by Mr. McClean to the Cape Observatory.

Sir William Huggins (*Ast. Nach.* 149, 231) moreover points out that about 10 lines attributed by Neovius to oxygen appear in the spectra of β *Orionis* and β *Lyræ*. In a later note he calls attention to the fact that in β and γ *Orionis* there appears a strong line coinciding with a strong nitrogen line, and in the latter star there are several other nitrogen lines. Herr Belopolsky (*Ast. Nach.* 151, 37) states that nitrogen lines appear in *P Cygni*. Sir Norman Lockyer in several papers published during the year refers to results obtained with the 42-inch Spottiswoode induction coil in a comparison of the spectra of the arc and an intense spark. He has given special attention to lines which are intensified or enhanced in the spark spectra, and

summarises results by distinguishing between lines of proto-metallic origin or enhanced lines, and lines of metallic origin. He identifies most of the lines in *a Cygni* with proto-metallic lines (*Proc. R.S.* lxiv. 320, *Nat.* lix. 342). He studies the spectrum of silicium (*Proc. R.S.* lxv. 449, *Nat.* lxi. 262), and identifies several strong stellar lines—*e.g.* in β , γ , and ζ *Orionis*—with that element. Lines referred to by Dr. Gill as of unknown origin, and of great strength in the spectra of β *Crucis* and β and ϵ *Canis Majoris* at λ 4552.79, 4567.09, and 4574.68, are probably identical with the group C attributed by Lockyer to silicium. In a paper (*Proc. R.S.* lxv. 452, *Nat.* lxi. 263) Lockyer gives a "Preliminary Table of Wave-lengths of Enhanced Lines." Mr. J. Lunt has a paper (*Proc. R.S.* lxvi. 44) on Silicium lines in stellar spectra.

Classification of Stellar Spectra.—In the *Publications of the Potsdam Observatory*, vol. xii. part 1, Professor Vogel and Dr. Wilsing give the results of the examination of photographs of spectra of 528 stars. Guided by the Draper Catalogue they studied stars of the First Type not fainter than fifth magnitude between the Pole and -5° declination. The spectra, which were 10 mm. long between λ 370 and 448, and 0.2 mm. wide, were taken with exposures of 12 to 15 minutes with a single-prism spectroscope attached to the 13-inch photographic refractor. The work consists of (i) a catalogue of stars, following the introductory note, and description of the system of classification adopted by Professor Vogel; (ii) a section dealing with measurements of photographs relating to 130 stars (mainly helium stars) by Professor Vogel; and (iii) a comparison with results recorded in the Draper Catalogue and in "Spectra of Bright Stars" discussed by Miss Maury under Professor Pickering's direction (*Annals Harv. Coll. Obs.* xxviii. 1).

Professor Hale (*Astroph. Journ.* x. 87), in a note dealing with spectra of stars of Secchi's Fourth Type, shows that an important piece of work has been inaugurated at the Yerkes Observatory in a branch of stellar spectroscopy that gives promise of being as fruitful as it is difficult. Instrumental power is being pushed forward in a bold way, and portions of the spectrum of *Schjellerup* and other stars of even seventh and eighth magnitudes have been photographed with slit spectroscopes. M. Dunér (*Astroph. Journ.* ix. 119) gives an account of visual observations of spectra of stars of Secchi's Fourth Type (Vogel's III. b). Both he and Professor Hale and Mr. Eilerman seem to detect bright lines in the spectra examined, and evidence is rapidly being accumulated in order to settle this difficult question.

Reference to the three researches just named makes it clear that classification is entering on a new phase, in which observers confine themselves to careful study of a single type rather than range over the wide field of general classification.

In a wider field of suggestiveness Sir Norman Lockyer deals with a new set of observations obtained with the powerful induction coil already referred to, and applies them to explanation

of stellar phenomena, always presenting them, however, in terms of his particular modes of classification. In his papers "On the Order of Appearance of Chemical Substances at Different Stellar Temperatures" (*Proc. R.S.* lxiv. 396, and *Ast. Nach.* 149, 225) and "On the Chemical Classification of the Stars" (*Proc. R.S.* lxv. 186) he follows up lines of work already indicated in his paper "On the Chemistry of the Hottest Stars." The difficulty in this kind of work lies clearly in the choice of an indisputable scale or order of temperatures in stars.

Velocity in the Line of Sight.—Professor Vogel (*Sitz. ber. Berlin. Akad.* 1898 Nov., and *Astroph. Journ.* ix. 1) has investigated the spectrum of α *Aquilæ*, and finds no evidence of orbital motion such as was announced by M. Deslandres (*C.R.* cxxi.). Vogel concludes that the lines in this star are broadened in consequence of the rotation of the star.

Professor Campbell (*Astroph. Journ.* ix. 86) finds that ζ *Geminorum*, a well-known variable, has a variable velocity in the line of sight; and Herr Belopolsky (*Ast. Nach.* 149, 239) corroborates the observation, giving results of measurement of 15 photographs showing that the period of variation of velocity coincides with that of the light changes. Herr Belopolsky (*Mem. Soc. Spettro. Ital.* xxviii.) has continued his observations of the variable velocity of the fainter component of *Castor*, and finds that the line of apsides has a rapid movement, the period of revolution being 4 years 40 days. The period of this star in its orbit is 2.93 days.

Mr. W. H. Wright (*Astroph. Journ.* ix. 59) discusses the orbit of η *Aquilæ*. Herr Belopolsky had announced variability in this star's velocity in 1895 (see *Astroph. Journ.* vi. 392).

Professor Campbell (*Astroph. Journ.* ix. 31) discusses some remarkable observations of α *Ceti*, which have led him and Mr. Wright to make careful determinations of the wave-length of the hydrogen line H_{β} . The wave-length is found to be 4101.87, as compared with Rowland's value 4102.00 [cf. *Astroph. Journ.* ix. 50 (Wright) and ix. 211 (Jewell)]. Professor Campbell (*Astroph. Journ.* ix. 310) states that ι *Pegasi* and θ *Draconis* have variable velocities, and (*Astroph. Journ.* x. 178) adds ϵ *Libræ*, h *Draconis*, λ *Andromedæ*, ϵ *Ursæ Majoris*, and ω *Draconis* to the list of stars with variable velocity. He announces the discovery of the binary character of *Capella* (*ibid.* x. 177), a discovery independently made by Mr. Newall (*Monthly Notices*, lx. 2; see also *Observatory*, 1900, pp. 92, 93). Professor Campbell announces that *Polaris* is a multiple system (*Astroph. Journ.* x. 180), and Professor E. B. Frost also gives observations of this star (*ibid.* x. 184). Professor Campbell adds yet two more stars, β *Capricorni* and ν *Sagittarii*, to the list of stars with variable velocity (*ibid.* x. 241).

Reduction of Spectrum Measurements.—Astronomers have shown their appreciation of Dr. J. Hartmann's relation connecting wave-lengths and micrometric measurements by adopting it, one may almost say, universally. Dr. Hartmann finds (*Potsdam*

Observations, XII. ii.) that the best relation is of the form $\lambda - \lambda_0 = C/(R_0 - R)^a$, where λ_0 , R_0 , C are constants to be determined by the use of standard reference lines, and a is an index of value $\frac{5}{6}$. He points out that the approximation got by putting $a=1$ is very satisfactory. This relation had been first given by Cornu in 1881 (cp. Salet's *Spectroscopie*, Paris, 1883, p. 75), but, strange to say, it had fallen into disuse.

Dr. Gill (*Proc. R.S.* lxxv. 196, and *Astroph. Journ.* x. 276) gives yet another relation of the form, $\log(\lambda - \lambda_0) = (R_0 - R) \times \text{const.}$

Attention may be called to the convenient tables published by Dr. Schlesinger (*Astroph. Journ.* x. 1) under the title "Line of Sight Constants for the Principal Stars." Latitude and longitude are given for each of 371 bright stars visible from northern observatories, for the epoch 1900, together with a table of precessions in longitudes up to 1930. The value $8''.80$ is adopted for the solar parallax.

H. F. N.

Sir William and Lady Huggins's Atlas of Representative Spectra.

In the striking volume which has just appeared, published in such tasteful form as to recall some ancient volume rather than a modern scientific work, Sir William and Lady Huggins set forth an account of pioneering research in astrophysics. The volume contains a remarkable series of plates reproduced from photographs of stellar spectra between the wave-lengths 4870 and 3300. This series has doubtless determined the title of the volume, but the plates are accompanied by 165 pages of text, which contain much new and important matter, dealing, as the title-page indicates, with the "evolutional order of the stars and the interpretation of their spectra."

The Atlas forms Vol. I. of the Publications of Sir William Huggins's Observatory. The first chapter accordingly contains the history of the Observatory, dating from the year 1856, when the chief instrument was a five-inch equatorial by Dollond. The earlier work is left to speak for itself, as it appears in the titles of papers on the work done in the Observatory, and Sir William Huggins has confined himself entirely to the history of the development of spectroscopic observation, in which he has taken so leading a part. A list of 81 papers forms Chapter II., with no further commentary than appears in an attractive Initial, drawn, like many others in the volume, by Lady Huggins.

Then follows a description both of the methods of taking the photographs of stellar spectra and of the spectroscopes in use in the Observatory, including also a new and ingenious device for automatically giving the necessary breadth to the photographic stellar spectra during the exposures (p. 61).

The discussion of the evolutional order of stars is contained in Chapter VI. (pp. 65-106), and forms perhaps the most

important part of the volume. Following up the lines indicated in 1879 in his paper "On the Photographic Spectra of Stars," and emphasised in his Presidential Address to the British Association in 1891, Sir William Huggins now reviews more recent evidence. In his earlier work he chose as a true natural criterion, clearly indicating successive changes of density and temperature, the gradual increase in strength of the calcium lines, together with other changes in the spectra. He arrived thereby at an order or sequence of certain typical stellar spectra, and regarded it as possibly indicating the successive stages in the life changes through which a star passes. This scheme was in general agreement with that independently arrived at by Vogel in 1874.

Sir William Huggins (accepting Lane's work, which shows that a gaseous mass rises in temperature if, whilst it is compressed under gravitation, it remains subject to the laws of a purely gaseous body) sets forth general considerations which weigh with him in arriving at the conclusion that the Sun and *Capella* are types of the stars at the maximum temperature. He then replaces general considerations by a definite piece of evidence of the greatest importance, viz. that photographs of the ultra-violet region of various stellar spectra taken with special precautions, make it clear that the ultra-violet photospheric radiation, where it is undimmed by special absorption in the stellar atmosphere, is relatively to the blue more intense in Solar stars than in Sirian.

The evidence is at variance with that of other observers, notably Lockyer's; and the clear statement of a definite issue is a step of great value. The question is one that can be settled only by extreme care and with special instrumental appliances. Sir W. Huggins has got a range of spectrum from $\lambda 4870$ to $\lambda 3300$, and—most important of all—he has used a mirror for collecting the light which is passed into the spectroscope, and so he avoids all the difficulties introduced by chromatic observation in refractors.

Chapter VII. consists of a description of Historical Spectra which are reproduced in Plate 2. In this chapter also there is new matter and promise of more, for we have in it some of the results of recent investigations with respect to the *Andromeda* nebula, and learn that a new instrument has for some time been mounted in the Observatory for special work of this kind. The Atlas proper is discussed in Chapter VIII. (pp. 131–165), which is headed Preliminary Discussion of the Spectra on the Plates. The authors draw attention to the significance of the first word of the title, and add that their main object is to place in the hands of those interested in the subject representative spectra of the principal classes of star through a long range of wave-length. The text contains, among other important matters, a discussion of recent photographs of the spectrum of the *Orion* nebula; and the authors infer from the new evidence that the stars of

the Trapezium are physically and evolutionally connected with the great nebula, as was suggested in 1889. The connection is of great import, and the authors are led in great measure by consideration of it to choose the Helium star *Bellatrix* as representative of the earliest stage in evolution (leaving out of account the Wolf Rayet stars).

Though Sir William Huggins does not definitely state it, it would appear that the provisional order of evolution now adopted by him may be indicated as follows :—

Order adopted in 1899.

Bellatrix.
Rigel.
α Cygni (distinct individuality).
Regulus.
Vega.
Sirius.
Castor (fainter star).
Altair.
Procyon.
γ Cygni.
Capella [highest temperature].
Arcturus.
Betelgeuze.

Order adopted in 1879.

Sirius—*Vega*.
α Ursæ Majoris.
α Virginis.
α Aquilæ.
Rigel.
α Cygni.
 —
 —
Capella—The Sun.
Arcturus.
Aldebaran.
Betelgeuze.

For convenience the earlier order is also given. Each list begins with stars in an early diffuse state.

Dr. Isaac Roberts's Photographs of Stars, Star-clusters and Nebulae. Volume II.

Dr. Roberts has recently published a second volume of photographs of stars, star-clusters and nebulae. The first volume appeared in 1893. The present collection consists of 72 photographs on 28 plates, together with descriptive text and two charts illustrating measurements of stars and bright points in certain spiral nebulae. The reproductions are admirably carried out, and astronomers are thus, thanks to the public spirit of Dr. Roberts, put in possession of a very valuable collection of records printed in permanent ink. Dr. Roberts does well to call attention once more to the perishable nature of glass negatives; he gives numerical details of the decay of some negatives in his possession. On one plate he counted 403 stars shortly after the plate was obtained; nine and a quarter years later 131 of these stars had disappeared by fading, and similarly with other plates.

In more than one place in the volume Dr. Roberts refers to a very remarkable result. It would appear that an exposure of ninety minutes secures as many stars as an exposure of ten or

twelve hours on plates of like sensitiveness. The only effect of longer exposure is to give greater density of images. Dr. Roberts does not refer to the suggestion that has been made that this is a sign that light must be of a definite intensity in order to affect a photographic plate enough to give a developable image.

The photographs are arranged in the following order :—

Plates 2-9. Photographs of rich fields of stars and of clusters.

Plates 10-18. Photographs of spiral nebulae.

And following these are photographs of nebulae, of circular, annular, and irregular forms ; and, lastly, nebulae of large areas of cloud-like matter. In a volume that contains so many beautiful plates it is difficult to single out special instances. It is, however, perhaps allowable to call special attention to

Plate 5. Chart of stars in *Cygnus* (cf. vol. i. p. 111),

Plate 21. Nebula H. V. 14 *Cygni*,

Plate 22. N.G.C. 1499 *Persei*,

Plate 27. N.G.C. 2237-9 *Monocerotis*.

Dr. Roberts has measured the positions of 81 stars and condensations in and around the spiral nebula M. 51 relatively to the nucleus as photographed in 1898, and gives the results in a table. In the case of 14 of these he is able to make comparison with Lord Rosse's measures made in 1872-74, and finds evidence that movements have taken place in the intervening 26 years. (The interval is by a slip described in the text as 47 years.) Dr. Roberts warns us that the evidence must be accepted with caution. The movements are in some cases so large that we may hope that Dr. Roberts himself will be able to check them entirely from his own observations in the course of the next few years.

PAPERS READ BEFORE THE SOCIETY FROM MARCH 1899
TO JANUARY 1900.

1899.

- Mar. 10. Observations of *Eros* (1898 DQ.), made with the 30-inch reflector of the Thompson equatorial of the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.
- Note on Dr. Rambaut's remarks in the *Monthly Notices* for November 1898. David Gill.
- Occultations observed at the Royal Observatory, Cape of Good Hope, during the lunar eclipse of 1898 December 27. Communicated by H.M. Astronomer.
- Nebulæ observed at the Royal Observatory, Cape of Good Hope, during the year 1898. Communicated by H.M. Astronomer.
- On the use of the electric light for the artificial star of a Zöllner photometer. W. de Sitter.
- The Radiant Point of the April meteors (*Lyrids*). W. F. Denning.
- Theory of the motion of the Moon; containing a new calculation of the expressions for the coordinates of the Moon in terms of the time. E. W. Brown.
- General Catalogue of the Radiant Points of meteoric showers, and of fireballs and shooting stars observed at more than one station. W. F. Denning.
- Observations of Hind's variable Nebula in *Taurus*. E. E. Barnard.
- Determination of the diameter and compression of the planet *Mars* from observations with the Repsold heliometer of the Royal Observatory, Göttingen. (Second communication.) W. Schur.
- Periodic variation in the colours of the equatorial belts of *Jupiter*. A. S. Williams.
- Double Star observations, 1895-98. W. H. Maw.
- Note on the diurnal variations of the nadir and level of the transit circle at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.
- The Greenwich meridian observations of *Polaris* 1836-93, with reference to personality, the value of the constant of aberration, and the star's parallax. W. G. Thackeray.

- Apr. 14. Double Star observations, 1897-98. J. L. Scott.
Photographs of the Radiant of the *Leonid* meteors, and attempts to photograph the meteor stream. Isaac Roberts.
Further observations of comet Coddington (c 1898). John Tebbutt.
Results of micrometer measures of double stars made with the 28-inch refractor at the Royal Observatory, Greenwich, in the years 1896, 1897, and 1898. Communicated by the Astronomer Royal.
On the errors of star photographs due to optical distortion of the object glass with which the photograph is taken. H. H. Turner.
Observations of planet (433) *Eros*, and of comet Tuttle, made at the Radcliffe Observatory, Oxford. Communicated by the Radcliffe Observer.
Observations of planet *Eros* from photographs taken with the 30-inch reflector of the Thompson equatorial at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.
- May 12. Observations of Tuttle's comet (b 1899) made with the 30-inch reflector of the Thompson equatorial at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.
Observations of Swift's comet, 1899, made at Grahams-town, South Africa. L. A. Eddie.
Observations of *Mars* made at Mr. Crossley's Observatory, Bermerside, Halifax, during the opposition of 1898-99. Joseph Gledhill.
Longitude from Moon culminations. D. A. Pio.
Remarks on the paper by Professor W. Schur, together with determination of the diameter and polar compression of the planet *Mars* from observations with the Repsold heliometer of the Remeis Observatory, Bamberg, and with the Breslau heliometer at the Observatory, Strassburg, in 1879. Ernst Hartwig.
On the errors of star photographs due to optical distortion of the object glass with which the photograph is taken. (Second paper.) H. H. Turner.
Note on the spectra of γ *Cassiopeiae* and α *Ceti*. Rev. W. Sidgreaves.
Observations of the satellite of *Neptune* from photographs taken at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.
Note on the constitution of *Saturn's* crape ring. E. M. Antoniadi.
- June 9. On the curvature of star trails on a photographic plate as a means of investigating optical distortion. H. H. Turner.

- On the formulæ of reduction to the meridian of the observed zenith distances of stars. A. E. Young.
- A further investigation concerning the position error affecting eye-estimates of star magnitudes. A. W. Roberts.
- Equatorial comparisons of *Jupiter*, *Uranus*, and *Neptune* with certain stars in Newcomb's Standard Catalogue. John Tebbutt.
- Note on the nebula N.G.C. 6535. W. H. Robinson.
- Note on the construction and use of Réseaux. A. R. Hinks.
- Ephemerides of two situations in the *Leonid* stream. G. J. Stoney and A. M. W. Downing.
- Observations of comet *a* 1899 (Swift) made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.
- Ephemeris for physical observations of the Moon for the second half of 1899. A. C. D. Crommelin.
- Small nebulæ discovered with the Crossley reflector of the Lick Observatory. J. E. Keeler.
- Nov. 10. Note on the motion of *Jupiter's* red spot. C. Flammarion.
- Comparisons of the geocentric places of *Mercury*, *Venus*, *Mars*, *Jupiter* and *Saturn*, calculated from the tables of the American Ephemeris Office with the places calculated from Le Verrier's tables for the year 1901. A. M. W. Downing.
- The magnitude of η *Argûs*, 1899. R. T. A. Innes.
- Observations of *Mars* during the apparition of 1898-99. Rev. T. E. R. Phillips.
- On the optical distortion of a doublet lens. Capt. E. H. Hills.
- List No. 12 of nebulæ discovered at Lowe Observatory, Echo Mountain, California, for 1900-0. Lewis Swift.
- Further notes on *Saturn's* crape ring. E. M. Antoniadi.
- Note on the geographical position of the University Observatory, Oxford. A. J. Walker.
- Observations of *Jupiter* in 1899. W. F. Denning.
- Early history of the great red spot on *Jupiter*. W. F. Denning.
- Observations of *Jupiter* and his satellites made at Mr. Crossley's Observatory, Bermerside, Halifax, during the opposition of 1898-99. Joseph Gledhill.
- Tempel's comet, 1873 II. (c 1899), observed at Grahams-town, Cape of Good Hope. L. A. Eddie.
- Ephemeris for physical observations of the Moon for the first half of 1900. A. C. D. Crommelin.
- Observations of nebulæ made at the Chamberlin Observatory, University Park, Colorado. H. A. Howe.

- Nebulæ discovered at the Chamberlin Observatory, University Park, Colorado. H. A. Howe.
- The Bruce micrometer of the Chamberlin Observatory. H. A. Howe.
- On the probable motion of the annular nebula in *Lyra* (M. 57), and the peculiarities in the focus for the planetary nebulæ and their nuclei. E. E. Barnard.
- The exterior nebulosities of the *Pleiades*, with a drawing from the different photographs; and on the appearance of the involved nebulosities of the cluster with the 40-inch refractor. E. E. Barnard.
- On the diameters of *Ceres* and *Vesta*. E. E. Barnard.
- The theory of the Figure of the Earth carried to the second order of small quantities. G. H. Darwin.
- On the distribution of stars photographed at the University Observatory, Oxford, for the Astrographic Catalogue for zones $+25^{\circ}$ to $+29^{\circ}$. F. A. Bellamy.
- On the variation of personal equation with stellar magnitude in observations made at Cambridge, Berlin, and Greenwich; as deduced from measures of photographic plates taken at Oxford. H. H. Turner.
- Comparison of the diameters of the images of stars on the Greenwich astrographic plates with the magnitudes given in the *Bonn Durchmusterung*. F. W. Dyson and H. P. Hollis.
- Preliminary note on the spectrum of α *Aurigæ*. H. F. Newall.
- Dec. 8. Ephemeris for physical observations of *Jupiter*, 1899-1900. A. C. D. Crommelin.
- Note on the values of the coefficients of the terms of the third order in the new Lunar theory. E. W. Brown.
- Observations of the *Leonids* of 1899 made at the University Observatory, Oxford. H. H. Turner.
- On the proper motions of Berlin B, Nos. 5072 and 5073. F. A. Bellamy.
- New nebulæ discovered photographically with the Crossley reflector of the Lick Observatory. J. E. Keeler.
- Observations of the *Leonids* of 1899 made at Durham Observatory. Communicated by R. A. Sampson.
- On the relation between magnetic disturbance and the period of solar spot frequency. William Ellis.
- The extra-equatorial currents of *Jupiter* in 1899. Rev. T. E. R. Phillips.
- Mean areas and heliographic latitudes of Sun-spots in the year 1898, deduced from photographs taken at the Royal Observatory, Greenwich, at Dehra Dûn (India), and in Mauritius. Communicated by the Astronomer Royal.

Observations of the *Leonids* of 1899 November 14 and 15, made at the Radcliffe Observatory, Oxford. Communicated by the Radcliffe Observer.

Results of observations of the *Leonid* meteors of 1899, as seen from the Royal Observatory, Edinburgh. George Clark.

Observations of the *Leonid* meteors of 1899 made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

1900.

Jan. 12. Note on the variable star η *Argûs*. Col. E. E. Markwick.

Observations of meteors, 1899 November, made at the Royal Alfred Observatory, Mauritius. Communicated by T. F. Claxton.

Note on the physical constitution of the lunar surface. George Forbes.

The determination of selenographic positions and the measurement of lunar photographs. S. A. Saunder.

Observations of the lunar eclipse 1899 December 16 at the Liverpool Observatory. W. E. Plummer.

Some suggestions for the explicit use of direction cosines or rectangular coordinates in astronomical computations. H. H. Turner.

On the unpublished observations made with the transit instrument and quadrants at the Radcliffe Observatory, Oxford, between the years 1774 and 1838. A. A. Rambaut.

Observations of occultations of stars by the Moon and of phenomena of *Jupiter's* satellites made at the Royal Observatory, Greenwich, in the year 1899. Communicated by the Astronomer Royal.

Micrometric measures of β 883 with the 28-inch refractor at the Royal Observatory, Greenwich, in 1899. Communicated by the Astronomer Royal.

Ephemeris for physical observations of *Mars*, 1900-1901. A. C. D. Crommelin.

LIST OF PUBLIC INSTITUTIONS AND OF PERSONS WHO HAVE CONTRIBUTED TO THE LIBRARY, &C., SINCE THE LAST ANNIVERSARY.

Her Majesty's Government in Australia.
Her Majesty's Government in India.
The Lords Commissioners of the Admiralty.
The Italian Government.
The Norwegian Government.
British Association for the Advancement of Science.
British Astronomical Association.
British Horological Institute.
Camera Club.
Geological Society of London.
London Mathematical Society.
Meteorological Office.
Physical Society of London.
Royal Geographical Society.
Royal Institution of Great Britain.
Royal Meteorological Society.
Royal Observatory, Greenwich.
Royal Photographic Society of Great Britain.
Royal Society of London.
Royal United Service Institution.
Society of Arts.
University College, London.
Belfast Natural History and Philosophical Society.
Cambridge Philosophical Society.
Cambridge University.
Cardiff, Astronomical Society of Wales.
Dublin, Royal Irish Academy.
Dublin, Royal Society.
Dunsink Observatory.
Kew Observatory.
Leeds Astronomical Society.
Leeds Philosophical and Literary Society.
Liverpool Literary and Philosophical Society.
Liverpool Observatory.
Manchester Literary and Philosophical Society.
Oxford, Radcliffe Observatory.
Oxford, University Observatory.
Rugby School Natural History Society.
Stonyhurst College Observatory.
Truro, Royal Institution of Cornwall.

Adelaide, Government Observatory.
American Astronomical and Astrophysical Society.
Amsterdam, Royal Academy of Sciences.
Arcetri, Royal Observatory.
Athens, National Observatory.
Australasian Association for the Advancement of Science.
Baltimore, Johns Hopkins University.
Batavia, Magnetical and Meteorological Observatory.
Batavia, Natural History Society of Netherlands-India.
Belgium, Royal Observatory.
Berlin, Central International Geodetic Bureau.
Berlin, German Physical Society.
Berlin, German Transit of Venus Commission.
Berlin, Institute of Computation of the Royal Observatory.
Berlin, Royal Observatory.
Berlin, Royal Prussian Academy of Sciences.
Berne University.
Bombay, Government Observatory.
Bordeaux Observatory.
Bordeaux, Society of Physical and Natural Sciences.
Boston, American Academy of Arts and Sciences.
Brussels, Royal Academy of Sciences.
Buda-Pesth, Hungarian Academy of Sciences.
Buda-Pesth, Royal Hungarian Institute for Meteorology
and Terrestrial Magnetism.
Calcutta, Asiatic Society of Bengal.
Calcutta, St. Xavier's College Observatory.
Canada, Geological Survey.
Canada, Royal Society.
Cape of Good Hope, Royal Observatory.
Cape Town, South African Philosophical Society.
Catania, Royal Observatory.
Chicago Academy of Sciences.
Cincinnati Observatory.
Copenhagen, Royal Danish Academy of Sciences.
Cordoba, Argentine Meteorological Office.
Cracow, Academy of Sciences.
Dijon, Academy of Sciences.
Geneva, Society of Physics and Natural History.
Georgetown College Observatory.
Göttingen, Royal Academy of Sciences.
Göttingen, Royal Observatory.
Halifax, Nova Scotian Institute of Sciences.
Halle, Imperial Leopold-Caroline Academy.
Hamburg Observatory.
Harvard College Astronomical Observatory.
Helsingfors, Society of Sciences of Finland.
Hong Kong Observatory.
International Committee of Weights and Measures.
International Geodetic Association.

Italian Meteorological Society.
Kasan, Imperial University.
Kasan Observatory.
Kiel, Royal Observatory.
Leipzig, Astronomical Society.
Leipzig, Prince Jablonowski Society.
Leipzig, Royal Society of Sciences of Saxony.
Lick Observatory.
Lund Astronomical Observatory.
Madras, Government Observatory.
Madrid Observatory.
Manila Observatory.
Mauritius, Royal Alfred Observatory.
Melbourne, Government Observatory.
Milan, Royal Lombard Institute of Sciences.
Moncalieri Observatory.
Montevideo, International Solar Institute.
Munich, Royal Bavarian Academy of Sciences.
Munich, Royal Observatory.
Naples, Academy of Physical and Mathematical Sciences.
Natal Observatory.
New Haven, Connecticut Academy of Arts and Sciences.
New York, Columbia University Observatory.
O-Gyalla, Astrophysical and Meteorological Observatory.
O-Gyalla, Central Meteorological and Magnetical Observatory.
Ottawa, Meteorological Service of the Dominion of Canada.
Padua Observatory.
Paris, Academy of Sciences.
Paris, Astronomical Society of France.
Paris, Bureau of Longitude.
Paris, General Dépôt of Marine.
Paris, Mathematical Society of France.
Paris, Ministry of Public Instruction.
Paris Observatory.
Paris, Philomathic Society.
Perth Observatory, Western Australia.
Philadelphia, American Philosophical Society.
Philadelphia, Franklin Institute.
Philadelphia, University of Pennsylvania.
Pola, Meteorological and Magnetical Observatory.
Potsdam, Astrophysical Observatory.
Potsdam, Central International Geodetic Bureau.
Potsdam, Royal Prussian Geodetic Institute.
Poukova Observatory.
Prague, Imperial Observatory.
Queensland Branch of the Geographical Society of Australasia.
Rio de Janeiro Observatory.
Rome, Central Meteorological Office.

Rome, Italian Spectroscopic Society.
 Rome, Pontifical Academy *de' nuovi Lincei*.
 Rome, Royal Academy *dei Lincei*.
 St. Petersburg, Imperial Academy of Sciences.
 St. Petersburg, Russian Astronomical Society.
 San Fernando Observatory.
 San Francisco, Astronomical Society of the Pacific.
 Stockholm, Royal Swedish Academy of Sciences.
 Strassburg, Imperial University Observatory.
 Sydney, Government Observatory.
 Sydney, Royal Society of New South Wales.
 Tacubaya, National Astronomical Observatory.
 Tiflis, Physical Observatory.
 Toronto, Astronomical and Physical Society.
 Toronto, Canadian Institute.
 Toulouse, Academy of Sciences.
 Turin, Royal Academy of Sciences.
 Turin, Royal Astronomical Observatory.
 Upsala Observatory.
 Upsala, Royal Society of Sciences.
 Vienna, Imperial Academy of Sciences.
 Vienna, Imperial Austrian Geodetic Bureau.
 Vienna, Imperial Military Geographical Institute.
 Vienna, Imperial Ministry of Marine.
 Vienna, Imperial University Observatory.
 Vizagapatam, G. V. Juggarow Observatory.
 Washington, National Academy of Sciences.
 Washington, Office of the American Ephemeris.
 Washington, Smithsonian Institution.
 Washington, United States Naval Observatory.
 Yale University, Astronomical Observatory.
 Yerkes Observatory.
 Zürich, Central Meteorological Institute of Switzerland.
 Zürich, Geodetic Commission of Switzerland.
 Zürich, Society of Natural History.
 Zürich Observatory.
 Editors of the "American Journal of Mathematics."
 Editors of the "American Journal of Science."
 Editor of the "Astronomical Journal."
 Editor of "Astronomische Mittheilungen."
 Editor of the "Astronomische Nachrichten."
 Editors of the "Astrophysical Journal."
 Editor of the "Athenæum."
 Editors of the "Bulletin des Sciences Mathématiques."
 Editor of the "English Mechanic."
 Editor of "Himmel und Erde."
 Editor of "Indian Engineering."
 Editor of the "Naturwissenschaftliche Rundschau."
 Editors of "The Observatory."
 Editors of "Popular Astronomy."
 Editor of "Sirius."

R. G. Aitken, Esq.
Prof. L. Ambrohn.
M. Ch. André.
Sigr. F. Angelitti.
M. E. M. Antoniadi.
Sigr. S. Arcidiacono.
Prof. O. Backlund.
Sigr. L. Barbera.
Prof. E. E. Barnard.
J. Baxendell, Esq.
L. S. Benson, Esq.
Arthur Berry, Esq.
Rev. E. L. Berthon.
Herr F. Bidschof.
Padre G. Boffito.
Herr Leo Brenner.
J. H. Brown, Esq.
C. Burckhalter, Esq.
W. H. M. Christie, Esq.
W. A. Cogshall, Esq.
Rev. A. L. Cortie.
Prof. G. H. Darwin.
A. E. Douglass, Esq.
Dr. A. M. W. Downing.
M. Ch. Dufour.
E. W. Ellerbeck, Esq.
Dr. A. H. Fison.
Herr J. Fényi.
M. C. Flammarion.
Prof. J. Franz.
Dr. H. Fritsche.
M. R. Gautier.
G. Brown Goode, Esq.
Dr. E. Hartwig.
Dr. B. Hasselberg.
Prof. F. R. Helmert.
Rev. A. Henderson.
Prof. E. S. Holden.
L. Horton-Smith, Esq.
Senor J. F. Igúrbide.
Rev. S. J. Johnson.
G. H. Knibbs, Esq.
Herr von Kuffner.

M. A. Laussedat.
Prof. E. Lebon.
Prof. G. Lorenzoni.
W. T. Lynn, Esq.
Sigr. A. Mascari.
Arthur Mee, Esq.
Prof. E. Millosevich.
E. Muybridge, Esq.
Messrs. G. Newnes.
M. L. Niesten.
Sigr. A. Nobile.
Herr J. Palisa.
Sir C. E. Peek.
Prof. F. Porro.
M. W. Prinz.
Dr. A. A. Rambaut.
Prof. A. Riccò.
Dr. Isaac Roberts.
H. C. Russell, Esq.
S. R. H. Salmon, Esq.
William Schooling, Esq.
Prof. W. Schur.
Dr. T. J. J. See.
M. C. Sharp, Esq.
W. Arthur Smith, Esq.
M. S. Socolow.
Madame Souillart.
Lewis Swift, Esq.
W. Teasdale, Esq.
John Tebbutt, Esq.
Prof. D. P. Todd.
F. W. True, Esq.
Senor V. Ventosa.
F. W. Very, Esq.
Prof. H. C. Vogel.
Capt. J. Waterhouse.
Prof. L. Weinek.
Messrs. W. Wesley & Son.
E. T. Whittaker, Esq.
W. E. Wilson, Esq.
Prof. Max Wolf.
Dr. A. Wolfer.
Prof. C. V. Zenger.

ADDRESS

Delivered by the President, Professor G. H. Darwin, on presenting the Gold Medal of the Society to M. H. Poincaré.

THE medal of the Royal Astronomical Society is this year awarded to M. Henri Poincaré, member of the Academy of Sciences of Paris. As your President, the agreeable duty of presenting the medal to him devolves upon me, but before I do so I must endeavour to lay before you the grounds upon which the Council has made this award.

M. Poincaré's researches have been so diverse in character, and have been carried out with such a wealth of knowledge, that I feel but little confidence in my fitness to perform this arduous task; yet I cannot but rejoice that my tenure of this chair should have furnished me with the opportunity of paying the homage which is due to him for his great achievements in the field of mathematics.

A large part of his work is concerned with the development of the science of pure mathematics, and of this side of his activity I am quite incompetent to speak. But in awarding our medal we naturally think of the value of the contributions by the proposed medallist to our science. Now, although many of M. Poincaré's investigations have perhaps already found, or will at some future time find, their application in the problems of dynamical astronomy, yet it is not necessary to search for cases of possible applicability to astronomy to justify our award. I propose, then, to draw your attention to only three of his lines of research, and these have a directly astronomical scope. My choice is governed not only by the intrinsic interest of the results, but also by the fact that the subjects treated possess a special interest for me. I shall speak, then, of his researches on the dynamical theory of the tides, on figures of equilibrium of rotating masses of liquid, and on the theory of the motions of planets and satellites.

The first of these subjects is treated in two memoirs on the equilibrium and movement of the ocean.* The problem is surrounded by conditions of such intricacy that it seemed to the author advisable to consider the several difficulties separately, as a preliminary to the treatment of the question as a whole. He begins, then, by the equilibrium theory of the tides, but he

* *Liouville's Journal*, 1896, pp. 59-102, and pp. 217-62.

proposes to take into account not only the effect of the obstructing continents, but also that of the attractions of the sea on itself. This problem was solved long ago by Bernoulli for the case when there is no land, and some thirty years ago by Lord Kelvin when there is no mutual attraction of the water on itself.* Lord Kelvin's correction to Bernoulli's theory may be taken as meaning that there are on a certain complete meridian four points at which the semi-diurnal tide vanishes; two of these points are on the same side of the Earth in equal northern and southern latitudes, and the others are antipodal to the first two. There are also four other points on another complete meridian where the diurnal tide vanishes; two of them are in one quadrant in complementary latitudes, and the other two are antipodal to the first two. Lastly, there are two parallels of equal northern and southern latitude at which the tides of long period are evanescent. There are, further, four other points of doubled semi-diurnal tide, four of doubled diurnal tide, and two parallels (sometimes, however, imaginary) of doubled tide of long period.

The positions of these points and parallels are dependent on the distribution of land and sea. The numerical quadratures necessary for their determination have been carried out, and it appears that in every case the points or lines of evanescence or of doubling lie very close to the places where the tide in question absolutely vanishes in Bernoulli's theory.† Since it can make very little difference whether a tide of excessively small range is doubled or annulled, it follows that the correction for land is of little importance, at least when the attraction of the water is neglected.

The introduction of the effects of the mutual attraction obviously presents a problem of great difficulty. Although it is probable that the result would possess little practical importance, yet the question is undoubtedly an interesting one from a mathematical point of view. It is at this point that M. Poincaré takes up the problem, and he shows that it is possible, at least theoretically, to determine a series of harmonic functions by which the mutual gravitation of the ocean may be computed. These functions degrade into ordinary spherical harmonics when the land is all submerged. Lord Kelvin had expressed the opinion that mutual attraction would only change the results to an insignificant degree, but M. Poincaré, while not contesting the justice of this view in general, adduces considerations which seem to show that a distribution of land is imaginable, which might perhaps make the correction of material importance. But the verification of this conjecture would necessitate the complete calculation, which would present an absolutely inextricable complexity on account of the capricious forms of our continents.

Although it does not seem likely that these new harmonic

* Thomson and Tait, *Nat. Phil.* § 808.

† G. H. Darwin and H. H. Turner, *Proc. R.S.* 1886, vol. xl. pp. 303-15.

functions will ever be applied to terrestrial oceans, yet they may perhaps furnish a clue to the discussion of the tides of seas of simple forms, such as the quadrant or octant of the whole globe.

The author's next step is the discussion of the small free oscillations of a system about a configuration of equilibrium, and we are here concerned with principles of the widest generality. He proves that the problem of small oscillations resolves itself into the determination of the maxima and minima of the ratio of the kinetic to the potential energy ; and the transition is easy from the case of free oscillations to that of forced oscillations under the action of any perturbing forces. This generalisation forms the basis of the author's whole investigation, and he remarks that he found the first suggestion of it in the work of Lord Rayleigh.

Passing from the case of a finite number to that of an infinite number of degrees of freedom, the author then applies his general principle to the oscillations of liquid standing in a vessel of small dimensions. The vessel is then enlarged so that the free surface at rest cannot any longer be treated as plane, but must be considered as a portion of a sphere concentric with the Earth's centre. It appears that the mathematical analysis is the same as that involved in finding the oscillations of a stretched membrane of unequal density and thickness in its different parts. This problem had been previously treated by the author in another memoir.

This brings us to the end of the first paper, and the second begins with the discussion of the process called by Lord Kelvin the ignorance of coordinates. The so-called gyroscopic terms now appear in the equations of motion ; in the tidal problem they arise through the fact of the Earth's rotation, and they form a very essential feature of the whole.

The general principles of the motion in such cases are then applied to the consideration of the oscillations of liquid standing in a small rotating vessel. This problem had been treated previously by Lord Kelvin ; * and he found, amongst other results, that waves propagated along a rotating canal would behave differently on the right and left banks. In this he saw a probable explanation of the different behaviour of the tides on the south coast of England and on the north coast of France. Well, the tides on the coasts of the two countries do not differ so much as the treatment which the problem presented by them has received from Lord Kelvin here and from M. Poincaré in France. As might be expected, the latter obtains his solution from the maxima and minima of a certain ratio, which corresponds to that between the kinetic and potential energies in the simpler problems treated before.

* *Proc. R.S. Edinburgh*, 1879 March 17, or *Phil. Mag.* 1880 August, pp. 109-116.

The problem of the rotating vessel only differs from that of the tides in all its generality in the linear scale on which it is supposed to take place ; and the effects of the Earth's curvature may be introduced in the same way as in the case of the non-rotating vessel.

The object of these memoirs was not to attain a definite solution in any ideal concrete case, but was to show how the fundamental difficulties might be surmounted by mathematical analysis. Here, as elsewhere, M. Poincaré carries us far beyond the particular instance in view, and it may well be that the principles enounced will meet their actual application sooner in other fields than in the tidal problem.

Important as is the work of which I have just spoken, the memoir on the figures of equilibrium of rotating liquid* seems to me to stand on a much higher level, for it marks an epoch not only in the study of the subject itself, but also in that of many others. It may be that some of the generalisations to be found in it were floating more or less distinctly in the minds of his predecessors, but the theory of the stability of systems in equilibrium or in steady motion has undoubtedly been crystallised and rendered transparent by his efforts. So fundamental are the new conceptions introduced that a new phraseology has become necessary, and it has already been adopted in other investigations, which possess no superficial resemblance to that of which I am now speaking.

Let us imagine a number of mechanical systems which resemble one another in all respects save one, such as size or density or any other measurable quantity. Suppose, further, that the systems are all in equilibrium, and that they are arranged in the order of the magnitude of that one measurable quantity, then we may describe the whole array as a family of systems in equilibrium. Now mechanical systems are often susceptible of equilibrium in more than one configuration, and we may therefore conceive the existence of a second family, which differs from the first in that the equilibrium involves a different configuration of the parts. If we were to examine the two families, we should find that in each the arrangement of the parts changed as we passed along the series. Now it is possible that there would occur in one family a certain member which would resemble the corresponding member of the other family in all respects. If this were the case, this particular member of either family would be described as a form of bifurcation, because it would belong to both, and the two families might be regarded as branching out from it. Now, M. Poincaré proves that if we follow each family towards the form of bifurcation, the equilibrium in one of the families would be stable, while that in the other would be unstable ; the same would also hold good after the passage through the form of bifurcation, but the family which was stable

* *Acta Mathematica*, vii. 1885-6, pp. 259-380.

before would be unstable afterwards, and *vice versa*. There is accordingly exchange of stabilities between the two families. Moreover, the passage of a system from stable to unstable equilibrium necessarily implies that at the moment of change we are passing through a form of bifurcation. Hence the study of the stability of a system may afford notice of the existence of hitherto unsuspected arrangements in which equilibrium is possible. These ideas possess the widest generality, but this is not the place to discuss their fertile ramifications.

If a system in steady motion or one at rest be slightly disturbed, it is said to be stable if the oscillations continue to be small throughout all time. But the existence of even the smallest amount of frictional resistance may betray the fact that stability really means two very different things. In one case even infinitesimal frictional resistance may cause the oscillations to increase to such an extent as to completely change the whole configuration; in another the oscillations may gradually die out and leave the system in the same condition as that in which it was at first. Both systems are stable when there is no friction, but the latter is said to possess secular stability. In nature only systems possessing secular stability are permanent, although it may require a very long time for a system possessing ordinary stability to break down. M. Poincaré here pays a well-merited tribute to Lord Kelvin, who appears to have been the first to clearly indicate this important distinction between these two kinds of stability.

Thus far the discussion is applicable to mechanical systems of every kind, but it finds its special application in the determination of the figures of rotating fluid. It may be well to mention, by the way, that in the course of the paper M. Poincaré justifies a number of statements as to possible forms of equilibrium and their stability, which had been made by Lord Kelvin without proof.

We now come to the main object of the investigation. A planet formed of homogeneous fluid has the form of an oblate spheroid, and its equilibrium is stable. If its angular velocity of rotation be increased, its ellipticity will increase also, but the stability will diminish. When the ellipticity has increased to a certain definite extent, the stability ceases, and for more rapid rotation the figure becomes unstable. At the critical moment of change we are passing through a form of bifurcation, and we know that there must be another series of figures which also possesses that form. This other series consists of the ellipsoids of Jacobi, which have their three axes of unequal magnitudes. But there is one single member of Jacobi's series which is a figure of revolution, and this is identical with the form of bifurcation found by following the stability of the oblate figures. It is true that this Jacobian is also a limiting form, since the series ends there; but we need not stop to consider that point further. It follows from the principle of exchange of stabilities that for rotation slower than

the critical value the Jacobian was stable. All this was known before, but M. Poincaré's work has placed it in a new and clearer light.

Having followed the stable series of oblate ellipsoids of revolution up to the junction at the form of bifurcation, M. Poincaré shunts his train on into the stable branch line furnished by the Jacobian ellipsoids. He follows this branch until he finds the Jacobian to become unstable, and announces that there is a new form of bifurcation, and that a new branch line has been reached. And here the line is nearly blocked by mathematical obstructions, and he is only able to proceed just far enough to perceive that the new figure is pear-shaped, with its larger portion more or less spherical, and with an equatorial protuberance which we may liken to the stalk end of the pear.

This apparently abstract result elucidates the evolution of planetary systems in a very interesting way. Let us consider a rotating liquid mass slowly cooling. If the cooling is slow enough internal friction will cause the whole to revolve throughout with the same angular velocity. At first, when the density is small, the figure will be an ellipsoid of revolution, but slightly flattened; and as it cools the flattening will increase until at a certain stage the figure of revolution ceases to be a figure of equilibrium, and the ellipsoid commences to have an equatorial protuberance; it passes, in fact, into one of Jacobi's ellipsoids. The ellipsoid then lengthens, until at a certain stage it begins to acquire an unsymmetrical furrow in a plane parallel to the axis of revolution, and it becomes pear-shaped, with the axis of revolution at right angles to the core of the pear. "The larger part of the matter tends to approach the spherical form, whilst the smaller part projects from the ellipsoid at one of the extremities of the longer axis, as though it were trying to detach itself from the larger part of the mass. It is difficult to state with certainty what will happen then if the cooling continues, but one may suppose that the mass will go on deepening its furrow more and more, and then it will at last divide itself into two separate bodies by the throttling of the middle part." It is clear that a process of this kind may have played its part in the evolution of celestial systems, and the speculation seems to meet with confirmation from the forms observed in many nebulae.

M. Poincaré's paper came as a revelation to me, because, just at the time when it was published, I had attempted to attack the question from the other end, and to trace the coalescence of two detached bodies into a single one—but, alas! I have to admit that my work contained no far-reaching general principles—no light on the stability of the systems I tried to draw—nothing of all that which renders Poincaré's memoir one that will always mark an important epoch in the history not only of evolutionary astronomy, but of the wider fields of general dynamics.

I now come to the third contribution of our medallist to

astronomy, namely the work on celestial mechanics. The first of the three volumes* of which the book consists deals with the general principles of dynamics as applicable to the problem of the three bodies, the second is on the work of previous investigators, and in the third the author analyses the results at which he has arrived by the previous discussions. It is probable that for half a century to come it will be the mine from which humbler investigators will excavate their materials. The range of matter is so vast and the number of new ideas so great, that I find myself in considerable difficulty as to how to speak of this book. It would clearly be impossible within the limits of such an address as this to give even an outline of the methods and conclusions.

Under these circumstances, then, I shall limit myself to only one portion of the whole, and shall speak of that at no great length. The subject to which I refer is that of the so-called periodic orbits; and my choice is natural, since I have been myself a hewer of wood and drawer of water in that field.

It was Mr. G. W. Hill who first drew effective attention to this class of solutions of the problem of the three bodies, when he initiated his new method of treating the lunar theory.† I am proud to say that our Fellow, Mr. Ernest Brown, is now carrying on Hill's grand conception to its laborious end. Former mathematicians have, almost without exception, adopted the Moon's elliptic orbit as their starting-point. But the first and roughest approximation to the Moon's path is a circle round the Earth, and the ellipse is an attempt to improve on the circle. Now Hill saw that the early introduction of the ellipse brought in its train a whole series of difficulties, which would be avoided if, continuing to neglect the eccentricity, he improved on the circle by introducing at once the effects of solar perturbation. The distorted circular orbit possesses the great advantage that it always presents the same features towards the Sun and the Earth. It is accordingly possible to draw, with any desired accuracy, a certain definite curve on a plane carried round with the Earth in its orbital motion. This curve exhibits the leading features of the effects of solar perturbation for all time; it resembles an ellipse drawn about the Earth as centre, with the major axis in quadratures, and with the minor axis in syzygies. The principal solar inequality is the variation, and hence Hill describes this orbit as the variational curve, and he uses it as an orbit of reference for the Moon's actual motion. If the Moon had been started with a motion differing but little from actuality she would have followed the variational curve for all time.‡ The curve may then be appropriately termed a periodic orbit.

* *Les Méthodes Nouvelles de la Mécanique Céleste*. Paris, Gauthier-Villars. Vol. i. 1892, vol. ii. 1893, vol. iii. 1899.

† *Researches in the Lunar Theory*, Cambridge, U.S.A. 1877.

‡ Hill's simple variational curve was drawn on the hypothesis that the squares and higher powers of the Sun's parallax are negligible. But these

Hill afterwards introduced the eccentricity of the lunar orbit by reference to the variational curve, and he treated the subject by a fertile method of the highest originality.* He habitually restrains himself from every tendency towards exuberance of expression in his writing, and so I am perhaps deceived when I fancy that even he hardly realised the fundamental importance of what he had done. Speaking of Hill's papers, M. Poincaré writes: "Dans cette œuvre il est permis d'apercevoir le germe de la plupart des progrès que la science a faits depuis."† Although he also pays warm tribute to Gylden and to Lindstedt, I conjecture that it may have been Hill who stimulated him to his attack on the profound questions awaiting solution in celestial mechanics. But these are almost personal questions which have little bearing on the advance of science in itself.

The variational curve obviously does not stand isolated, but is merely a single member of a series of periodic solutions of the problem of the three bodies. These solutions, according to M. Poincaré, furnish the only breach by which we may hope to penetrate the fortress of a problem hitherto deemed impregnable. Their importance becomes manifest when I say that he has proved that a periodic solution may always be found which shall differ by as small a quantity as we please from any given motion of the perturbed body, however complicated that motion may be. It is true that the required periodic orbit may need to go through a very large number of circuits before its periodicity is completed.

Orbits of this kind are divisible into three classes: in the first, the inclinations and eccentricities are zero; in the second, only the inclinations are zero; and in the third, there are no limitations in these respects. In the cases of the variational curve and of the orbits which I have traced, the orbit of the perturbing body is circular, the whole motion takes place in the plane of the circle, and the periodicity of the perturbed body is completed after a single circuit; they belong to the first group. As in the investigation of figures of equilibrium, so here also we meet with orbits of bifurcation, limiting forms and exchanges of stability; and this illustrates the wide generality of the ideas which I attempted to sketch earlier in my address.

Mr. Hill had traced a certain cusped orbit in which the Moon might have moved, and thinking that he had found a limiting form, described it as the Moon of greatest lunation. But M. Poincaré showed that Hill had been misled, and that the cusp is succeeded by looped orbits. Lord Kelvin chose one of them

further approximations may be introduced, and the above statement then becomes correct. The simple curve is symmetrical both as to the lines of syzygies and of quadratures, but the corrected curve is only symmetrical as to syzygies.

* "On Part of the Motion of the Lunar Perigee, &c.," *Acta Mathematica*, vol. viii. pp. 1-36.

† *Méc. Céleste*, vol. i. Introduction.

as an example to illustrate a method of graphical construction by which a curve may be traced by means of its curvature.* The successive transformations of these orbits are elucidated by the series of figures which I have drawn, and I now see that they will terminate their career, at least as simply periodic orbits, in a form which has been called by M. Burrau an orbit of ejection.† As this latter name is hardly sufficiently explanatory in itself, I may say that the perturbed body is supposed to be ejected from one of the two principal bodies along the line of syzygies, or it may fall inward tangentially to that line. These orbits furnish an interesting and peculiar form of periodicity, but the limitation of my time prevents me from referring to them in greater detail.

Another class of orbits, as pointed out by Poincaré, is said to be asymptotic; they are closely akin to the periodic orbits. In this case the body draws asymptotically near to a certain curve, and after performing an indefinite number of circuits, may gradually depart therefrom again. Certain figure-of-eight orbits which I have drawn are intimately connected with these asymptotic orbits.

M. Poincaré has made a searching examination of my figures by means of his analysis, and has put his finger on a weak spot. I had carelessly treated two sets of curves as being continuous with one another, but he shows that my scheme cannot be maintained. I had already arrived at the same conclusion from an entirely different point of view in consequence of the criticism of Mr. S. S. Hough, but it was too late to correct the oversight before the paper was published. Mr. Hough has now a paper in the press for the *Acta Mathematica*, wherein the true sequence of the orbits will be exhibited. I have already by me a large part of the computations required for the actual drawing of a new family of orbits, whose existence I did not suspect.

There can, I think, be little doubt that the investigations of M. Poincaré and of his followers will ultimately afford some sort of explanation of the empirical law of Bode as to the distances of the planets from the Sun; and such an explanation will almost of necessity render intelligible the sequence of processes by which the solar system has been evolved. In the case of the satellites revolving about my ideal planet *Jove* I found that there was a tract near the planet which might be occupied by stable orbits, that this was surrounded by a belt, within which no stable orbit was possible, and that this was again succeeded by a belt of stability. These results are, of course, only true of simply periodic orbits; and I was perhaps rash in saying that I saw in them some indications of a law analogous to that of Bode. Nevertheless, I notice also in M. Poincaré's book a suggestion which may perhaps tend in the same direction. The inferior planets circling round the Sun in my ideal problem were stable up to a certain

* *Phil. Mag.* vol. xxxiv. 1892, pp. 443-8.

† *Ast. Nachr.* Nos. 3230 and 3251.

distance, and then became unstable, and he conjectures that the further pursuit of this family of orbits will lead us back again to a belt of stability. I hope to test this interesting suggestion. But even this meagre sketch has already occupied too much time, and I will say but few words more.

The leading characteristic of M. Poincaré's work appears to me to be the immense wideness of the generalisations, so that the abundance of possible illustrations is sometimes almost bewildering. This power of grasping abstract principles is the mark of the intellect of the true mathematician; but to one accustomed rather to deal with the concrete the difficulty of completely mastering the argument is sometimes great. To the latter class of mind the easier process is the consideration of some simple concrete case, and the subsequent ascent to the more general aspect of the problem. I fancy that M. Poincaré's mind must work in another groove than this, and that he finds it easier to consider first the wider issues, from whence to descend to the more special instances. It is rare to possess this faculty in any high degree, and we cannot wonder that the possessor of it should have compiled a noble heritage for the men of science of future generations.

In handing this medal to you, M. Poincaré, I desire to say on behalf of the Society that in seeking to pay honour to you we feel ourselves honoured.

The meeting then proceeded to the election of Officers and Council for the ensuing year, when the following Fellows were elected :—

President.

E. B. KNOBEL, Esq.

Vice-Presidents.

Sir R. S. BALL, M.A., LL.D., F.R.S., Lowndean Professor of Astronomy and Geometry, Cambridge.

A. A. COMMON, Esq., LL.D., F.R.S.

G. H. DARWIN, Esq., M.A., LL.D., F.R.S., Plumian Professor of Astronomy, Cambridge.

H. H. TURNER, Esq., M.A., B.Sc., F.R.S., Savilian Professor of Astronomy, Oxford.

Treasurer.

W. H. MAW, Esq.

Secretaries.

F. W. DYSON, Esq., M.A.

H. F. NEWALL, Esq., M.A.

Foreign Secretary.

Sir WILLIAM HUGGINS, K.C.B., LL.D., D.C.L., F.R.S.

Council.

W. H. M. CHRISTIE, Esq., C.B., M.A., F.R.S., Astronomer Royal.

A. M. W. DOWNING, Esq., M.A., D.Sc., F.R.S., Superintendent of the *Nautical Almanac*.

J. W. L. GLAISHER, Esq., M.A., Sc.D., F.R.S.

Capt. E. H. HILLS, R.E.

FRANK McCLEAN, Esq., M.A., LL.D., F.R.S.

Major P. A. MACMAHON, R.A., F.R.S.

Capt. WILLIAM NOBLE.

A. A. RAMBAUT, Esq., D.Sc., Radcliffe Observer.

G. M. SEABROKE, Esq.

E. J. SPITA, Esq.

W. G. THACKERAY, Esq.

E. T. WHITTAKER, Esq., M.A.

CONTENTS.

Fellow elected	PAGE 295
Candidate proposed	<i>ib.</i>

REPORT OF THE COUNCIL TO THE EIGHTIETH ANNUAL GENERAL MEETING OF THE SOCIETY :

Progress and Present State of the Society	<i>ib.</i>
Treasurer's Account from 1899 January 1 to December 31	296
Treasurer's account of sale of Consols and reinvestment	298
Report of the Auditors	300
Trust Funds	<i>ib.</i>
Assets and Present Property of the Society	301
Stock in hand of Volumes of the <i>Memoirs</i>	302
Stock in hand of Volumes of the <i>Monthly Notices</i> , &c.	303
Celestial photographs published by the Society	304
Instruments belonging to the Society	306
The Gold Medal	312
Publications of the Society	312

OBITUARY :

List of Fellows deceased during the year	313
Charles William Baillie	<i>ib.</i>
Rev. Edward Lyon Berthon	314
James Carpenter	316
Samuel Cooke	318
Nathaniel Everett Green	<i>ib.</i>
John Marshall	320
Benjamin Theophilus Moore	321
John Newton	<i>ib.</i>
Charles Leeson Prince	<i>ib.</i>
George Carter Pulsford	324
James Cruikshank Roger	<i>ib.</i>
Rev. John Slatter	325
Hale Wortham	<i>ib.</i>

PROCEEDINGS OF OBSERVATORIES :

Royal Observatory, Greenwich	327
Royal Observatory, Cape of Good Hope	332
Royal Observatory, Edinburgh	340
Armagh Observatory	342
Cambridge Observatory	343
Do. do. the Newall Telescope	345
Dunsink Observatory	347
Durham Observatory	<i>ib.</i>
Glasgow Observatory	348
Liverpool Observatory	349
Radcliffe Observatory, Oxford	350
University Observatory, Oxford	353
Temple Observatory, Rugby	354
Stonyhurst College Observatory	<i>ib.</i>

Contents.

PROCEEDINGS OF OBSERVATORIES— <i>continued.</i>	PAGE
Markree Observatory (Col. Cooper's)	355
Mr. Edward Crossley's Observatory, Bermerside, Halifax	356
Wolsingham Observatory (Rev. T. E. Espin's)	<i>ib.</i>
Sir William Huggins's Observatory, Tulse Hill	<i>ib.</i>
Rousdon Observatory, Lyme Regis (Sir C. E. Peek's)	357
Birr Castle Observatory (the Earl of Rosse's)	<i>ib.</i>
Dr. Isaac Roberts's Observatory, Crowborough Hill, Sussex	358
Mr. W. E. Wilson's Observatory, Daramona, Streete, co. Westmeath	360
Hong Kong Observatory	<i>ib.</i>
Madras and Kodaikānal Observatories	<i>ib.</i>
Melbourne Observatory	361
Sydney Observatory	362
Measurement of the Sydney and Melbourne Astrographic plates (Joint Report)	363
Natal Observatory	364
Perth Observatory, Western Australia	<i>ib.</i>
Lovedale Observatory, South Africa (Mr. A. W. Roberts's)	365
Mr. Tebbutt's Observatory, The Peninsula, Windsor, N. S. Wales	366
NOTES ON SOME POINTS CONNECTED WITH THE PROGRESS OF ASTRONOMY DURING THE PAST YEAR:	
Discovery of Minor Planets in 1899	368
The Comets of 1899	370
Meteoritic Observations during the year	372
Solar Activity in 1899	375
Total Solar Eclipses	376
Astronomical papers of the <i>American Ephemeris</i>	<i>ib.</i>
Variation of Latitude	378
The Variations of Gravity at the Earth's surface	379
The measurements of Base Lines and Standards of Length	380
The Astrographic Chart and Catalogue	<i>ib.</i>
Star Catalogues	382
Double Stars	385
Longitude Determination	387
Stellar Spectroscopy in 1899	388
Sir William and Lady Huggins's Atlas of Representative Spectra	392
Dr. Isaac Roberts's Photographs of Stars, Star-clusters, and Nebulæ, Vol. II.	394
Papers read before the Society from March 1899 to January 1900	396
List of Public Institutions and of Persons who have contributed to the Library, &c., since the last Anniversary	401
Address delivered by the President, Prof. G. H. Darwin, on presenting the Gold Medal to M. Henri Poincaré	406
Election of Officers and Council	416

Printed by SPOTTISWOODE & Co., New-street Square, London; and Published at the
Apartments of the Society, March 1900.

